MACKENZIE VALLEY PIPELINE INQUIRY

IN THE MATTER OF AN APPLICATION BY CANADIAN ARCTIC GAS PIPELINE LIMITED FOR A RIGHT-OF-WAY THAT MIGHT BE GRANTED ACROSS CROWN LANDS WITHIN THE YUKON TERRITORY AND THE NORTHWEST TERRITORIES FOR THE PURPOSE OF THE PROPOSED MACKENZIE VALLEY PIPELINE

and

IN THE MATTER OF THE SOCIAL, ENVIRONMENTAL AND ECONOMIC IMPACT REGIONALLY OF THE CONSTRUCTION, OPERATION AND SUBSEQUENT ABANDONMENT OF THE ABOVE PROPOSED PIPELINE

(Before the Honourable Mr. Justice Berger, Commissioner)

Yellowknife, N.W.T.

April 8, 1975.

PROCEEDINGS AT INQUIRY

VOLUME XXV

ALLWEST REPORTING LTD.,
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APPEARANCES:

Mr. Ian G. Scott, Q.C. Mr. Stephen T. Goudge, Mr. Alick Ryder and Mr. Ian Roland	for Mackenzie Valley Pipeline Inquiry;
Mr. Pierre Genest, Q.C. Mr. Jack Marshall, Mr. Darryl Carter and Mr. John Steeves	for Canadian Arctic Gas Pipeline Limited;
Mr. Reginald Gibbs, Q.C. Mr. Alan Hollingworth	for Foothills Pipelines Ltd.;
Mr. Russell Anthony, and Prof. Alastair Lucas	for Canadian Arctic Resources Committee;
Mr. Glen W. Bell and Mr. Gerry Sutton	For Northwest Territories Indian Brotherhood and Metis Association of the Northwest Territories;
Miss Lesley Lane	for Inuit Tapirisat of Canada and The Committee for Original Peoples' Entitlement;
Mr. Ron Veale and Mr. Allen Lueck,	for Council for Yukon Indians
Mr. Carson H. Templeton,	for Environm ental Protection Board;
Mr. David Reesor,	for Northwest Territories Association of Municipalities;
Mr. Murray Sigler,	for Northwest Territories Chamber of Commerce.

I N D E X

EXHIBITS:

Yellowknife, N.W.T.
April 8, 1975.

(PROCEEDINGS RESUMED PURSUANT TO ADJOURNMENT)

MR. SCOTT: Mr. Genest has something that he'd like to deal with first, Mr. Commissioner.

MR. GENEST: In the last session a number of undertakings to provide information were given by me, and I thought it might be a convenient time to do some tidying up.

I have given copies of these documents to the Commission secretary, and I believe some copies have been placed on your desk, sir. The first matter was a sheet entitled:

"Drill Hole Data for Pipeline Routing In Yukon and Northwest Territories, incorporating the East Fort Simpson amendment and cross-delta alternative."

That was requested by Mr. Scott, and I suggest the best way to deal with it is perhaps --its in tabular form, if we could just mark it as an exhibit, if that is satisfactory.

THE COMMISSIONER: Certainly.

(DRILL HOLE DATA FOR PIPELINE ROUTING IN YUKON & NORTHWEST TERRITORIES, INCORPORATING EAST FORT SIMPSON AMENDMENT & CROSS-DELTA ALTERNATIVE MARKED EXHIBIT 87)

MR. GENEST: Then we were asked to, I believe by you at page 2744 of the transcript, as to whether there was a report as to a

reconnaissance of the Pointed Mountain line, and we were asked to look up our list of documents. We have done so. It is item 104 on our list of documents. We have it available. Mr. Bell was interested in the subject matter, and I have advised Mr. Bell that he can look at the report in our library up here.

The next matter, sir, is a little more extensive, and it arises out of questions asked by you at page 2723 of the transcript, and perhaps to introduce it properly I should just read the exchange that took place, it is found in Volume 23 on March 21st, and Mr. Clark was testifying and you said, sir, and I quote:

> "I take it at the moment you are not really able to give me any specific instances where the route was moved owing to the necessity of avoiding an environmentally sensitive area?"

The answer was:

> "I can think of a couple of examples, and they've already been discussed, of pretty large movements, but the alignment sheet work, for instance the give and take, I can't recall those from memory, I can recall it happening and I can undertake to look at records that are available."

And you then said, sir:

> "Yes, I think I would appreciate it if you would because you and your colleagues will be back again in April."

And Dr. Clark has obtained the necessary information

and I thought if it was convenient I would get him to deal with that matter now. He has brought the alignment sheets and I have again placed with the Commission secretary some three documents, the first entitled:

"A Brief Summary of Environmental Concerns and Route Changes arising from April 9-13th Meetings."

A second sheet headed:

"Geotechnical Considerations relative to route changes made following the April 9-13 Meetings,"

and the third sheet entitled:

"Additional changes in routing made to avoid conflicts with Mackenzie Highway or to improve compressor station locations."

(BRIEF SUMMARY OF ENVIRONMENTAL CONCERNS & ENGINEERING RESPONSES & ROUTE CHANGES ARISING FROM APRIL 9-13 MEETINGS MARKED EXHIBIT 88)

(GEOTECHNICAL CONSIDERATIONS RELATIVE TO ROUTE CHANGES MADE FOLLOWING APRIL 9-13 MEETINGS MARKED EXHIBIT 89)

(ADDITIONAL CHANGES IN ROUTING TO AVOID CONFLICTS WITH MACKENZIE HIGHWAY OR TO IMPROVE COMPRESSOR STATION LOCATIONS MARKED EXHIBIT 90)

JOHN IVOR CLARK,
GARRY WOOD HOLLINGSHEAD,
EDWARD CHARLES McROBERTS,
WILLIAM ALEXANDER SLUSARCHUK,
NORMAN REUBEN MORGENSTERN,
RICHARD H. COOPER,
R.H. HARDY,
GUY LESLIE WILLIAMS, resumed:

MR. GENEST:

If I could ask Dr. Clark to deal with these now briefly so as to make them intelligible?

WITNESS CLARK: These alignment sheets that I have here, Mr. Commissioner, which I will turn over to Mr. Genest, are copies of the alignment sheets that were sent to the environmental consultants prior to the April review in 1973. We have marked on these in red --

THE COMMISSIONER: Prior to the big meeting?

A Yes sir.

Q Between your engineering people and your environmental people?

A Yes, that was the April 9th to 13th meeting, and we marked on these in red the changes that were made. Now, when these were sent out and while they were reviewing them, to suggest changes that they might see appropriate, we were also continuing with our own review. However, no changes were made until the meeting, and following the April 13th meeting there were a total of 31 changes on these sheets that were considered. 13 of these were at the direct suggestion of the environmental people involved. The remainder were those changes that our geotechnical people had suggested on the basis of terrain. Generally related to terrain stability, and they were then discussed, the changes were made, and the 13 that were suggested by the environmental group, six

changes were made, and of the other seven it was either not technically feasible to make the change or that further study of that particular concern had put the concern to rest.

Now about the same time or shortly after, before the alignment sheets that were filed were completed, we also made a further five changes with respect to the proposed Mackenzie Highway to avoid conflicts, and these were incorporated and also marked in red here, so that the red lines on this particular document coincide with the alignment sheets that are filed, and have been examined here as an exhibit.

MR. GENEST: I'm sorry, Dr. Clark, the red on the alignment sheets that was added shows the change that took place.

A Shows the change that took place.

Q Right, and can we get our paper work in order, Dr. Clark, permit me --

A Yes, the first piece that you have mentioned is the list that was drawn up by Mr. Watson following the April 9th to 13th meeting. Now, this list is a brief summary of what took place and why it took place.

The second document --

THE COMMISSIONER: I wonder just while we're at it, could the list be marked? Does that make sense, Mr. Genest?

MR. GENEST: Yes, I'd like

to tender it, sir.

A The second one, sir, at least what I'm calling the second one, sir, is the geotechnical considerations relative to those particular changes.

THE COMMISSIONER: That will be marked, too?

MR. GENEST: Right.

MR. GENEST: What will be the number of the first one?

THE SECRETARY: 87.

MR. GENEST: 87.

MR. SCOTT: Just so that I have them in order, has the first bore hole sheet been marked?

MR. GENEST: That's 87. So the first sheet entitled:

"The following is a brief summary of the environmental concerns etc."

would be Exhibit 88.

The next sheet entitled

"Geotechnical considerations,"

and so on is 89.

And what is the next sheet?

WITNESS CLARK: What I'm calling the third one is the additional changes in routing made to avoid conflicts with Mackenzie Highway

or to improve compressor stations location --

MR. GENEST: I think that's 90.

A And either appended to that, if you wish, or as a separate one is the geotechnical considerations of those five changes, and I'd suggest that that be appended to that sheet.

MR. GENEST: Well, mine is separate. I think everybody's is separate.

THE COMMISSIONER: Let's call it 90-A.

MR. GENEST: Right.

(GEOTECHNICAL CONSIDERATIONS OF ADDITIONAL CHANGES MARKED EXHIBIT 90-A)

THE COMMISSIONER: So we know it relates to 90.

MR. GENEST: All right.

WITNESS CLARK: Unless you wish, sir, I didn't propose to read all of these into the evidence. I think I could draw attention to give examples to a few here. One would be a geotechnical change that occurred at that period which is shown on sheet 1-C-0200-1003. This is in the vicinity of the Malcolm River.

Q That would be on the first, item 3 on Exhibit 88?

A Item 3, I picked a number at random here, for example.

Now this was a-- there were two changes made on this sheet.

MR. SCOTT: What page is this on?

MR. GENEST: The front page of Exhibit 88 and it's also referred to at the top of page 2 of Exhibit 89. Have I got this straight? Exhibit 89 is the geotechnical considerations.

A It would have the same number, it would be --

Q Yes, item 3 there, sheet 1-C-0200-1003.

A Correct.

Q Right.

A There were two changes. The first was made to avoid a poor gully crossing. The length of line affected by the change was 3.3 miles. It added about 100 feet to that length. The

terrain in that area was such that we move upstream, reduced our slope angles and provided an incidental improvement on the other minor drainage ways. It added one side bend and the general construction conditions were basically unchanged.

The second change on that sheet covered a length of line of approximately 8.5 miles. It added about 800 feet to that length, and it was made to avoid slumping ice wedge polygons on the bank of the Malcolm River. Hence there was a reduction in the potential buoyancy and stability problems.

That was, as I mentioned, one of the changes that was recommended and accepted by the geotechnical people who were continuing route refinement during that period.

Now an example of a change to satisfy an environmental concern, is what I have listed here is No. 12 on sheet 1-D-0200-1006.

Q That's on the third page of Exhibit 88?

A Yes. Now this is an area east of Old Crow where it was pointed out that the lakes west of the Driftwood River were very good for waterfowl, and the recommendation of the environmental consultants was to move the line north. The line was moved in accordance with the recommendations. The re-routing increased the length through that area by 0.7 miles, almost three-quarters of a mile. The terrain was similar but the new location had generally

Q What number is that, sir?

A That is No. 13.

Q 13.

A We examined that suggestion and found that it was unacceptable geotechnically. The proposal would place the line in an area of very high buoyancy and some thermal erosion, with a much less favorable river crossing. We felt in that instance that the first crossing chosen was the preferable one.

Q Sir, why did they want to move the line two miles north of Berry Creek?

A The concern was with the crossing, this was noted in the minutes of the environmental meeting, the notes we had read, it's a fairly high use area for migrating caribou, moose, fur-bearers and sometimes beaver. We felt that further study relative to the terrain where we were crossing as compared to the suggested area would cause less environmental impact and this was suggested to them at that second meeting.

Now another example of a fairly major move is No. 19, sheet 1-A-0200-1003, and 1004. This is the Holmes Creek area just south of Swimming Point. It was suggested that we move further from Holmes Creek, and again we were parallelling the creek on ground that was of somewhat higher relief and gave us the shortest line through the Swimming Point crossing. There was concern that

that was an area of high fur-bearer productivity and that we should move back from the creek. So for a distance of about nine miles the line was re-located, from Milepost 25 to 34. Lateral movements up to three-quarters of a mile were made to avoid parallelling the creek too closely. This added about 6/10ths of a mile to the length throughout there. The terrain types that are crossed are similar at both locations, but the old location, the first one we have chosen was the best topography that gave the most direct route to the Swimming Point crossing.

The new route was less favorable with respect to the significant increase in potential buoyancy problems. The construction requirements would be similar for both locations, but the new location would require more weighting.

Now another example is 23, the environmental comment was relative to sheet 1(b) 0200-1011. And their concern was with the existence of rafter nests in that area on the particular river that appears on that alignment sheet. In order to assess this concern our environmental manager checked the area with Mr. Richard Fyfe, of the Canadian Wildlife Service, and we were advised that our route was at least four miles up from the closest rafter nest site and that this was therefore no need to change it to avoid a conflict.

What I have listed is number 30 on sheet 1(b) 0200-1039. The enviromental consultants had pointed out that the pipeline route was passing very close to a lake which is important. And they preferred that the route stay at least 400 yards from that lake. We were able to re-locate it approimately a 1000 feet to the west, but if we had moved it further it would have put it in conflfict with the Mackenzie Highway so there was another physical constraint. Subsequent discussions they considered this an adequate move. It changed terrain somewhat, but the length was not significantly changed. A slight increase, something of the order of a 100 feet, I believe.

Now, on the five other changes, that are listed as made to avoid routing conflicts. For instance --

MR. GENEST: This is on Exhibit 90?

A Yes.

Number 1 there, on Sheet 1(b)-0200-1014. This is an area near Good Hope. We located to the west to avoid a possible conflict with the highway. There was no significant change in line length. It added two more bends to deal with. The terrain types were similar, but the peat crossed was a somewhat greater length at the new location and the construction would be similar, except that more weighting would be required there.

Well, these five then go on to describe either a move. Number 2 relates to the Mackenzie Highway, Number 3 an area where the line was moved to improve a compressor station location. And the reason that they are listed here is because they are all made about the same time, and they are all shown on this set of alignment sheets which you may want to include with your filing.

That's all that I was going to cite as examples, but all of the changes shown here are listed with a summary of the reasons and geotechnical considerations.

MR. GENEST: Sir, would it meet with your approval if I filed this stack of alignment sheets which shows actually the detail of the work?

MR. SCOTT: I take it, Mr. Genest, that on the alignment sheets the new route or the change is in red, is that correct?

MR. GENEST: That's correct. And the old route is in black.

THE COMMISSIONER: Excellent.

MR. ANTHONY: Mr. Commissioner, may I also direct a question on that regard? The gentleman's name escapes me for the moment, but he was with Mr. Williams on the first panel.

MR. GENEST: Mr. Watson?

MR. ANTHONY: Yes, that's correct, Mr. Watson, who had early alignment sheets that were also presented at this meeting, showing the location of the highway. The alignment sheets that are now going to be exhibits, do they also include the information he had about the highway location for that environmental meeting in April?

MR. SCOTT: I think Mr. Commissioner if I can interrupt my friend, the real concern is that Mr. Watson, or Dr. Watson, I forget his title, indicated that he would file the alignment sheets that were presented to the environmentalists. Now it may be that exhibit 91 is in fact, Exhibit 91 if you take off the red lines, is infact the alignment sheets that were sent to the environmentalists.

WITNESS CLARK: These are the same reproductions of the alignment sheets that were presented to the environmentalists.

MR. ANTHONY: These alignment sheets that you have there that are Exhibit 91 also include the highway on it, do they?

WITNESS WILLIAMS: This ~~does~~ set not include the highway, but the ones that were filed

as the Exhibit do show the highway location.

MR. ANTHONY: You mean the actual application alignment sheets?

A Yes, right.

MR. ANTHONY: I'm sorry, perhaps I'm mistaken. I understood from Mr. Watson's evidence that there was an alignment sheet showing the highway location as they understood it, prior to this, at the same time as this aligmment sheet showing the proposed route. And that this may be, the highway shown on those sheets may be somewhat different than the highway as shown on the final application.

A I'm sure you're right, and at the meeting we had a working set of alignment sheets similar to these with the highway marked on in probably red or blue pencil or something. Just for our own reference at the meeting. I don't know if those are still available or not. This is the only set we were able to find of the alignment sheets are set at that meeting, because we've modified them to make the alignment sheets for the application. The line that was shown in the April meeting was erradicated from the originals. This is just a set of prints that we've were able to find in the archives that was used at that meeting.

Now, I'm not sure that we can find that set, that working set, that does have the highway location as we knew it at that time.

MR. ANTHONY: Well, Mr. Commissioner, I believe I have Mr. Watson's statement

and I can go back to the transcript, saying that he does have those sheets, and I thought we had undertaken that those sheets would be provided.

MR. GENEST: Well let me check that Mr. Anthony.

THE COMMISSIONER: You can find that reference Mr. Anthony and show it to Mr. Genest and Mr. Scott and let's see what Mr. Genest says about it.

(ALIGNMENT SHEETS MARKED EXHIBIT 91)

MR. GENEST: Sir, that leaves me with a further enquiry by you in connection with the Fort Simpson route changes. Mr. Williams, Dr. Clark was not heavily involved in that aspect of the matter. Mr. Williams is waiting for some dates, and I've spoken to Mr. Scott and I think we can give you a better picture of that tomorrow morning. And that sir, concludes what I had today.

THE COMMISSIONER: Thank you.

CROSS-EXAMINATION BY MR. SCOTT:

Dr. Cooper, I'd like to turn to one matter you raised, and that is the question of the measurement of scour due to major ice-jams, and the work you've done in connection with that. And I take it just so we'll be clear, that that is the problem that was identified as unsolved in the Blench Associates report of July, 1974. Is that correct?

WITNESS COOPER: A Yes, in that particular report we identified it as not having come up with a number if you like. We had done a lot

of work at that time to --

Q Yes, I think the word utilized in that report, and in the Northern Engineering Services report on Ice Conditions of August, 1974, was in fact unsolved, wasn't it?

A That's correct.

Q Yes, and I take it that what you have told us last time was that as a result of the analytical work underway for one to two years in which you've been in charge, finished only a month ago, that problem can now be regarded as solved?

A It can be regarded as solved in that the work was directed at arriving at a estimate, a very conservative estimate of the maximum scour that could develop.

Q And I take it that the at one stage that you regarded the problem as unsolved because you were unable to predict with any assurance at that time, the outside limit of the scour?

WITNESS COOPER: No, I wouldn't say that we were unable to predict. We had not carried the analysis through at that point in time to obtain the predication.

Q All right, well let me put it this way. Would it be correct to say that you regarded the problem as unsolved because your analysis was insufficiently developed to predict the depth of scour with assurance.

A That's fair to say.

Q And I take it that you now feel confident that you can predict the depth of scour as a result of ice jams with confidence.

A Yes, we do.

Q Yes, and would it be -- and I take it that this problem is one that will be relevant at a number of major crossings.

A By "a number" I believe it to be relevant at the Mackenzie River crossing at Point Separation to the greatest extent. The checks or the analysis would also be carried out on the Mackenzie River crossing upstream of Simpson, although the conditions there are such that the problem should exist to the same extent.

Q How about the Peel River?

A The Peel River by its nature during breakup, we feel, is not an ice-jamming hazard, or the same hazard for a jam to develop does

not exist there.

Q I take it that the soil bottom of the Peel River is one that is susceptible to scour at the crossing point.

A Yes, it is, to the point where bedrock is reached, and of course bedrock is shallow on one side.

Q Yes, well then why do you say that this isn't a problem that is likely to confront you at the crossing of the Peel River?

A Because the hazard for jamming is not the same as it is on the Mackenzie. What happens is when the Peel River breaks up we normally have very high backwater from the Mackenzie Delta, and the breakup is quite orderly as opposed to the Mackenzie.

Q Well now, the solution to the problem has led you, as I understand it, to be able to say to the Commission that you can predict with some assurance the depth of scour due to ice jams.

A We can predict with some assurance the maximum conceivable scour. I'm not in complete agreement that this is the best prediction. I think it's highly over-conservative.

Q Right, but that seems to me at the moment to be all to the good. You can predict the maximum level depth of scour.

A Yes.

Q And the obvious importance of that is that you want to know that so that you can determine the depth at which the pipe has to be buried below that river.

A That's correct.

Q And that not only for integrity of pipe reasons, but for environmental reasons as well.

A Yes, and for a third reason, what are the problems of constructability.

Q Yes. Well now, I take it that the analytical work that you have done really is an analysis that has produced a hypothesis.

A I'm not sure that I understand what you mean by the analysis producing a hypothesis.

Q Well, let me put it this way, and it may be simplistic and you'll tell me if it is, but I take it that a skilled and experienced engineer can sit in his laboratory or in his armchair and develop a thesis, and that is one of the things that you have done in approaching this problem.

A Well, in approaching the problem we have come up with -- we've developed an analytical model that involves a number of elements that generally are established theories either in open water flow analysis or I'm sorry, open channel flow analysis, sediment transport, and ice jam mechanics.

Q Yes,but am I right that

in looking at this analytical model what you have done is you have applied some theories to it and developed a thesis?

A In a sense that's correct.

Q Yes, and you'd agree with me that the accuracy of the thesis has never been tested on the ground.

A The accuracy of the combined model has never been tested on the ground, that's true. The elements of it, in many cases, have.

Q But to carry it to its logical conclusion, the depth of scour has never been measured at any major river crossing.

A For the events we are predicting scour, that's true. However, I should point out that the inputs to the analysis are -- the combination of inputs are more severe than to our knowledge has occurred and has been observed so that even if we could measure scour with this combination of inputs, it hasn't been done.

Q Well, I take it that what you have is you have some information as to the measurement of scour in open water locations.

A Yes, that's correct.

Q Yes, and in addition to that you have a conceptual model, an analytical model that you look at, and then you have one year of observing the water of the Mackenzie and other rivers.

A Of observing the water?

Q Of observing the ice jams.

A We've had two years of that.

Q Two years of that, but to be perfectly clear, I take it that neither you nor indeed anybody else has ever been able to measure the scour depth at or near an ice jam.

A A severe ice jam, that's correct.

Q And isn't it so that the model you have utilized to develop your prediction is really in its nature two-dimensional?

A That's correct.

Q Yes, it shows a cut of the river and you work how the currents work and the pressure of the ice in the water and so on.

A Yes.

Q In that cut.

A Yes, that's correct.

Q Well, isn't it so that in the nature of ice jams they are three-dimensional and that is that there is a width of ice as well that may have -- I don't say does, but may have -- important consequences in terms of scour depth.

A Yes, and of course we're accounting for this in our application of the modelling results. What we are doing is we're taking the results of the two-dimensional model, as you put it, and we're saying that this at this time should be

measured down, not from the average bed elevation but from the deepest or the lowest bed elevation.

Q When you say "measured down" do you mean rendered more conservative?

A Well, there have been findings that would indicate that as scour develops beneath the ice jam, the entire ice jam, that the section, the cross-section would become more uniform. Now if this is true, then there would be some justification, some argument for measuring this from an average, predicted scour from an average bed elevation, We, however, feel that more information is required to justify this move and we're recommending that they measure it from the lowest bed elevation.

Q Well, isn't it again fair to say that that is a conceptual hypothesis that hasn't been tested anywhere?

A Yes. Well, what is a conceptual hypothesis?

Q Well, it's a rationalization made by you of anticipated events.

A It would certainly be to some extent a rationalization if I recommended we measure it from the average bed level, but I think we're being highly conservative.

Q I understand that you think you're being conservative, and I take it the reason you emphasize how conservative you're being is because at least as far as scour from ice jams is

concerned the whole issue is hypothetical in the extreme, and that's why you have to be so totally conservative.

A Again I'm not clear on your use of the word "hypothetical".

Q Well, let me come at it this way. You have told us that in open water scour cases, you measure the potential for scour depth by applying a factor that may vary from 1.5, if you're being liberal, to 4 if you're being conservative.

A It varies within that range. It varies because of the conditions at the particular river.

Q All right. What I'm saying to you is this, isn't it so that open water scour is a relatively well-understood problem?

A It's certainly more understood than the ice jam.

Q And it's not only understood in theory but there have been measurements made of scour holes in open water which will test and help you develop the factors.

A That's what the factors are by and large based on.

Q Yes, so that in open scour even with that ability to test the depth of the scour you still have to produce a wide range of factors to cover every eventuality, 1.5 to 4.

A That's correct, yes.

Q Well now I put it to you that if, knowing as much as you do about open water scour, and bearing in mind the variety of range of factors that you need to cover all the water scour holes that are possible and that have been measured, isn't it very risky at this date to say, "We can predict the maximum scour depth under ice jams," when no measurements have been taken?

A Well, if you'll let me draw the analogy between the prediction that we're discussing and the open water scour conditions, my biggest concern is that where we have factors between 1.5 and 4 in the open water case, and if we were to express the ice scour case in terms of a factor, I feel that the one we've got would be up around 5 or 6 in that it is probably not a good design, it's too conservative. But based on our information we have to go --

Q Yes, but I take it you're going to 5 or 6, is that what you're saying, under ice jams?

A That's -- well, no, we're not using the factor, I just wanted to draw that analogy.

Q All right, but even if you did how would you know that that would be adequate?

A It's a matter of having confidence in the elements of our analysis and the level of conservatism.

Q Well to revert to yesterday's question, aren't you really therefore taking a risk that the scour depth under ice jams never measured will not exceed the depth that you predict?

A I'd rather express it in degree of conservatism, which I suppose is the opposite to risk. I guess I can discuss it in terms of risk, though, and I think in coming up with this prediction we are taking a very, very minimal risk.

Q Well now, let me come to one other matter, suspended crossings. I take it that the only crossing on the Mackenzie River that's ever been made has been made by telephone lines.

A No, I understand there were some pipelines on the canal system that crossed the Mackenzie or a part of it.

Q When you say "a part" do you mean a tributary?

A It may have been just across to an island, I'm not certain. I'd have to check the records on that.

Q And a report made to Northern Engineering by Lamb McManus has asserted that overhead crossings of the Mackenzie are feasible. You're aware of that report, aren't you?

A I haven't read it, no.

Q And I take it that --

WITNESS HARDY: I know the report.

Q Is that correct, Dr. Hardy?

A I initiated that study, that is correct.

Q Yes, and I take it, Dr. Cooper, that your own report on twinning the rivers listed overhead crossings as an alternative in one location.

WITNESS COOPER : My own report, sir?

crossing, I think, on this pipeline as a viable alternative. Do you recall which that was?

A that's part of this pipeline.

Q I see, well what is it again? I mean --

A It's the Elk River in South-Eastern B.C.

Q So would it be fair to say that we stand in this position, that we heard what has been said about rivers, we have one consultant's report that says that they are -- that overhead crossings are viable, that's the Lamb Report. We have you in one case recommending an overhead crossing as an altnernative.

A No sir, I don't think we recommended it as an alternative, but in any event --

Q Well, let me just read what you say:

"The alternatives include stability analyses, monitoring of slope movements, minor re-location , andin one case an overhead crossing."

A All right, I stand corrected, it is an alternative.

Q Yes. I'm not saying it was your first choice, I'm simply saying that you regarded it as a viable approach to the problem.

A That is a possibility,sir, yes.

Q And I understand from what we heard yesterday that although he seems unable to persuade his clients, Dr. Hardy as well regards it as a viable alternative, is that so, doctor?

WITNESS HARDY: Yes. I should add, Mr. Scott, that the Lamb McManus Report was prepared by their structural engineers, and when they say it's possible to build overhead crossings, they do that, they say that from a structural point of view. They are not taking into consideration any of these other factors that I pointed out yesterday, that are objections.

Q No, but Dr. Hardy, I understood you to say yesterday that you yourself favored overhead crossings, though you had some difficulty for reasons of economics and maintenance, of persuading your clients. Is that a correct account of what you said?

A In this particular case it's a viable solution to many crossings from the structural point of view, and from other considerations that I have in mind that go somewhat beyond the Lamb McManus Report. In the case of the Elk River, you see, this was in consultation with them on other pipelines I had recommended an overhead crossing for other pipelines. They were never built.

Q Well, let me put this proposition --

A They were submarine

crossings.

Q Let me put this proposition to Dr. Cooper. I take it, it would be fair to say that while it may create some other problems, such as maintenance and cost, an overhead crossing will remove a numer of the environmental concerns that are associated with burying a pipeline under the bed of the river.

WITNESS COOPER: If we're talking about the crossing where ice jam related scour is a prime consideration --

Q Well, let's talk about overhead crossings generally first. Am I not correct in saying that if you have an overhead crossing you don't have any of the problems or the dimension of the problems of digging in the river and moving the bed and all the rest of it?

A That's correct, only where the overhead crossing does not require a support, pier or piers in the river.

Q All right. But if there is no pier required in the river, it removes a substantial number of the environmental concerns that are -- that relate to digging in the river and burying a pipe.

A well of course, if they span the entire river I would have no input into it.

Q Well, that would be a disadvantage, and I take it also that with respect to

scour under ice jams it removes -- an overhead crossing removes the necessity of depending on your recent calculations.

A I believe on the rivers that we're crossing with overhead crossings, that you would require probably two piers in the river and the problems may be greater.

Q Yes. The problems, however, would be different, wouldn't they, because you would just have one or two piers?

A We are still dealing with the scour, the piers would tend to increase the scour and we're dealing with ice loading.

Q Have you done any work on scour on piers as a result of ice jams?

A Not as a result of ice jams, no.

WITNESS HARDY: There has been work done, though, on smaller rivers in Alberta, Mr. Scott.

Q But just so we'll be clear, Dr. Hardy, and I want to be sure I have you correctly, at page 2819 yesterday when speaking of overhead crossings, you said,

"I like them myself, you see, but I have lost every argument with my pipeline friends when I have suggested, 'Well, here is a place maybe you should be talking about an overhead crossing.'"

Is that your view?

A That's exactly what I said.

Q All right, that's fine, I just wanted to have it --

A Remember, sir, that I'm an old broken-down structural man, the same as Dr. Cooper likes to play around with rivers, I liked to play around in structures years ago.

Q Well, all right, thank you very much. We have that clear. I just wanted to be sure that that was an accurate account of your evidence. Now, Dr. Cooper, can I come to another problem and that relates to the existence of deep holes in the major delta channels, and I take it that you are aware of the phenomena that I think I am talking about?

WITNESS COOPER: I believe so, yes.

Q And this is an important question, is it not, particularly in view of the cross-delta proposal?

A Yes, I think it is.

Q And isn't it correct to say, Dr. Cooper, that you have taken -- or your people have taken -- extensive soundings in the major river channels of the delta?

A We have taken considerable, we have done a considerable amount of sounding work in the vicinity of the crossings that are being proposed.

Q Yes, and I take it that

in the course of that sounding work you found very deep holes in some of those channels.

A By and large the deep holes that we found could be explainable in terms of open water hydraulics. There were a number of them at locations that were not crossing, I should point out, that are anomalous admittedly in terms of normal open water hydraulics.

Q How deep would some of them be? What was the deepest you found?

A I believe the deepest we found was in the order of 100 feet.

Q Yes.

A In that order, I could be --

Q Yes, what is the depth of the channel in the delta?

A Well, of course this varies considerably.

Q What's the average depth?

A It varies considerably from a matter of ten feet in some of the very broad ones to an average depth of say 60 feet in some of the channels.

Q Now I put it to you that those holes cannot be explained on the basis of any existing knowledge of channel hydraulics.

A Some of the holes are at locations that are difficult to explain. There have been

hypotheses put forward that would indicate that their development could have been through a process of thermal degradation and that the flow situation is such that it will prevent their infilling. However, I should point out that the locations were crossing we have found no evidence of such holes, or we found no evidence in that type of location.

Q I understand that, doctor or you wouldn't be crossing. It would be foolhardy to cross in the face of one of those holes, wouldn't it?

A Not necessarily.

Q Well, it would be risky.

A If we're -- if we could demonstrate that we were in, before final design, that we were in a depositional environment it may well be the best place to cross.

Q Well, let me ask you this. Would you agree with me that many of those holes are of unknown origin?

A I would agree that there are questions about their origin.

Q Yes, and none of those questions have been resolved except by -- and I don't say this disrespectfully -- except by armchair hypothesizing.

A The origin of the holes has not -- of some of them, of the few anomalous holes, has not been conclusively demonstrated.

Q And indeed you've reported

to that or Dr. Hollingshead has in a report called:

> "Preliminary design of six major river crossings north of the 60th Parallel of Northern Engineering Services,"

dated August of 1974, where you say in Chapter 4, paragraph 1-A:

> "The reach of the east channel from Swimming Point north has been extensively sounded and exhibits a number of deep local scour holes of unknown origin."

A From Swimming Point north, that is?

Q Yes.

A Yes.

Q Well, that's true, isn't it?

A There is evidence of a sequence of deep holes in essentially the middle of the channel from Swimming Point north to the Beaufort Sea.

Q And I take it that if I were to suggest to you that nothing really is known about the origin of these holes, except by hypothesis, you wouldn't disagree with that.

A The origin of the ones downstream, I would have to agree with you, yes.

Q Yes, and if I were to suggest to you -- and perhaps it's in the report -- that nothing was really known about their life , that

is whether they got deeper or filled in, except as a matter of hypothesis, you wouldn't disagree with that.

A At this point in time, no, but I should point out that we are now undertaking studies in the field to gain the information so that we can prove that.

Q And if I would suggest -- and perhaps you've beaten me to it by already suggesting it -- that these holes could be the result of the melting of ground ice below the channel, you wouldn't be in a position to either assert that or deny it with any certainty. It's just another hypothesis, isn't it?

A Yes, thats correct.

Q But if that hypothesis were correct, that is that these holes were caused by the melting of ground ice, wouldn't it be extremely difficult to construct buried river crossings in the delta where those holes are, or where they develop?

A No, definitely not. All we would have to do is demonstrate in the course of obtaining data for developing final designs that the ground ice did not exist where we were crossing.

Q Well, let me ask you this, referring to what we were saying yesterday, in suggesting a crossing of the delta, at whatever location, bearing in mind how little is known about these holes, aren't you taking a calculated risk in the absence of precise knowledge? I'm not criticizing it, I'm just asking it.

A Well I believe there have been some drill holes made. I think --

Q Well, aren't you taking a calculated risk of some proportion?

A Not with the knowledge of what the ice conditions are, and we have got holes in there, to some extent.

Q Well, there aren't any drill holes up there? Where are the drill holes in the Cross Delta Route?

WITNESS HOLLINGSHEAD: A Yes, there have been some test holes made along the Cross Delta alternative.

Q Are they shown on the alignment sheets that were provided to us? Would they have been shown if they had been done?

WITNESS WILLIAMS: A The drill holes within the window of the mosaic that were done in the Delta are shown on the alignment sheets that were filed. In addition to those holes there were some deeper holes drilled at locations, at a previous route location that we had that do no fall on the window of the mosaics, but I'm sure the results of those deep holes are in some of the reports that have been recently filed.

Q How deep are the bore holes that are shown at the Delta river crossings? And how many approximately are there?

A Generally they were 20 feet deep, 10 to 20 feet deep. But the deep ones that I'm speaking of to try to test this hypothesis of thermal degradation of insitu ice, were in the neighbourhood of 200 feet deep.

Q Yes, but those are the ones that aren't shown on your alignment sheets?

A That is correct.

Q Yes, and I take it that those were done because Dr. McKay said that ground ice could be found in those locations at a depth of 150 Feet. Isn't that so? Isn't that why you went off and did this work, because he'd said that those bore holes aren't deep enough for a Delta crossing?

A Well, I don't recall particular input from Dr. McKay, but certainly we went in to test to see if there was massive ice adjacent to these deep holes.

Q Well, how many holes have been done at a depth exceeding 100 feet on the Cross Delta route?

WITNESS HOLLINGSHEAD: A I think there are three or four such holes and those are the test data from those holes are available in a report which has been filed.

Q How long is the Cross Delta route of which you are speaking?

A Which part of it?

Q At the Delta.

A It's about 35 miles of twin line there.

Q Yes. Well now, Dr. Cooper bearing in mind those facts, are you able to say with absolute assurance that the crossing that you have

described is, with that knowledge, secure?

WITNESS COOPER: A The Cross Delta crossings?

Q Yes.

A I would have to say for some of the Cross Delta channels that we would need some additional data before aproving the final designs on it.

Q Wouldn't it be fair to say Dr. Cooper that in this case, you have the hypothesis again, isn't that fair?

A Yes, basically that's correct.

Q But isn't there an additional factor that in this case you haven't even, and I don't say this critically, but the knowledge has not yet been able to give you a hypothesis for the origin of these holes?

A Well no, we certainly do have an hypothesis for the origin of those holes.

Q Well, what's your hypothesis?

A Well, I have two if you like.

Q Well, you can have two, but it seems to me that it becomes then quite hypothetical. Tell us what your two are?

A That they could be due to degradation of ice lenses or permafrost. Or that

it could be due to some of the reversing flow that we get in some of these channels.

Q And wouldn't you agree with me that it is much, much too early to say what they cause of them is?

A What the--

Q Hole? If you've got two hypotheses, I take it you haven't selected between them yet?

A Well, let me make an illustration, or again a comparison. I don't judge the status of those designs as being that much different to say the status of a design of one of the rivers, one of the more conventional rivers, where we do not have final design data.

Q But do you concur in Dr. Clark's conclusion with respect to the Cross Delta route, you have all the tools that you need to solve the problem with assurance?

A I believe we have all the tools, yes.

Q And by tools, you mean you have the analytical techniques?

A That's correct.--

Q Untested on the ground?

A -- but they require some data to - -

Q Yes. Now, let me come to one other matter, and that is gouging of the channel

by ice cakes. And I take it that this is a phenomenon that has been observed that when an ice cake is unended and proceeds down the river?

A Yes, it can be upended and literally moved down the river, partially being floated by the flow, and partially rolling on the bed.

Q Yes, and isn't it true that in the Beaufort Sea where of course there are bigger ice cakes, substantially bigger perhaps, the scouring resulting has been as deep as 30 feet?

A I couldn't answer that.

Q Would that surprise you?

A Again, I don't have any data on it. I would have to see the data.

Q And I take it that Mr. Nuttal of your firm has reported that the ice cakes on the Mackenzie River could goudge the river bed and endanger any buried pipeline, if it's not buried deep enough?

A I would like you to read those words. I don't know whether he said 'endanger' or not.

Q No, he didn't, you are quite right. He says this, " in several instances sizeable ice flows were observed to be upended and rolling along a sheer line such that their corners undoubtedly came in contact with the bed. At no time during the field observation program was it possible to directly observe the magnitude of bed

goudging resulting from this process." Would you agree with that?

A Yes, I would.

Q Yes, and I take it therefore that with respect to ice cakes upended, we have no information as to the depth of scour?

A We have no--

Q At least from Mr. Nuttall.

A -- just a minute. We have no direct observation of the depth of scour. However, we have on the basis of that report presented data to Northern Engineering Services of the, what we considered to be the largest cake that could roll on the bed. They have estimated from geotechnical considerations how much scouring could take place. I should also like to point out that the rolling of these cakes along the bed, normally occurs along the shear lines during breakup. Now these are near the banks, they are not out in the middle of the river. They are definitely not out in the deepest portion of the river, because the cakes just wouldn't reach the bed there.

Where this goudging takes place we're going to have much more cover by a considerable degree than, cover over top of the pipe, than goudging could ever expose, so --

Q Well, how do you know that? Let me ask you this. You say that you presented data to Northern Engineering that disclosed how deep

the goudging would be?

A Well Dr. Hollingshead can talk about that.

Q Yes, well let me just ask you first. He can add to it. I take it when you say you presented data, you presented again in fact a hypothesis. There was no measurement of any of this?

A A hypothesis based on field observations of the largest ice cakes that were observed to be rolling.

Q Yes, but you didn't measure any of the goudge marks?

A Not, we didn't make any direct measurements of goudging, no. Not in the river bed, on the banks, yes.

Q You measured the sizes of the ice cakes?

A That's correct.

Q Now, Dr. Hollingshead, did you want to add something?

WITNESS HOLLINGSHEAD: A I was just going to say that if you took the largest potential ice cake, as was suggested by Mr. Nuttall and combine that with say the worst bed condition, loose sand, we did some preliminary calculations which indicated that you would have/possibly something in the order of 7 to 8 feet of penetration .

Q Well Dr. Cooper, or Dr. Hollingshead, isn't it clear that this phenomenon has

never really been reported in the literature?

WITNESS COOPER: A In the published literature I suspect not, but it is reported in the literature that you are referring to.

Q Well, yes, it's reported by Mr. Nuttall, who doesn't go on to say this, but in terms of the published literature apart from Arctic Gas and Northern Engineering, it's not a matter that's ever been dealt with?

A No, I suspect it will be in the not too distant future.

Q Again, you are the first. You are the pioneers. But let me put this to you. I take it that it very probably is a phenomenon that is associated with the Mackenzie and very few other rivers?

A I believe that it would be fair to state that the Mackenzie would be a severe case. It would definitely be associated with other rivers, such as the Peace or the Athabasca.

Q Yes. Well now, I put it to you again that you find yourself with a hypothesis that is untested by any field work that involves measurement of results?

A Pure measurement of results, you're basically correct here. However, I should point out that there is a level of confidence implicit in the lack of observation of the results when we do river surveys. In other words, we do not come out with, shall we say scour holes, or very narrow

holes that could be attributable to this. This indicates that it is not a severe problem, although it doesn't conclusively demonstrate it.

Q Well let me ask you this. Would it lead you to re-evaluate your position and perhaps adopt a more conservative hypothesis still, if if were shown to your satisfaction that there were scour marks in the Beaufort Sea that were in excess of 30 feet deep? Would that have any bearing as far as you are concerned?

A We must keep in mind, of course, the ice strength and the ice forces in the Bering Sea are much greater.

Q Yes. What I'm basically asking --

THE COMMISSIONER: Excuse me, what sea are we in at the moment? Did you say, Bering Sea?

A I'm sorry, I meant Beaufort.

MR. SCOTT: We're both adrift in one sea or the other.

Q Would that worry you or cause you to re-evaluate your hypothesis?

A Not really, in that in light of the findings we have made and the observations we have made, we could take probably three or four times that amount of goudging if you like, and it would still not be of concern with the crossings that we are

proposing. We are going to have that much cover where it can occur.

WITNESS MORGENSTERN: Could I comment here, Mr Scott. I have had some contact with the Beaufort Sea problem as a consultant on design of off-shore drilling structures against the ice in that area. The mechanics of that process differ very greatly from the mechanics of the ice goudge process that you are addressing here. The energetics of the, the phenomenon that are driving the ice differ. The strength of the ice differs very greatly as Dr. Cooper pointed out, and it's a relatively straightforward calculation to demonstrate that the amount of goudge that can develop under river actions is much less than the depth of burial that we are talking about.

I think that the allusion to the mechanics of Beaufort Sea goudging is a very different animal.

Q Well, I take it that we are agreed then, that even if that fact were demonstrated, it isn't something Dr. Cooper that would worry you?

WITNESS COOPER: A No, we look on the goudging of the river bed as being a factor that doesn't go deep enough to govern the designs. The other considerations such as open water scour and ice-jamming scour are much more prominent.

Q Well, isn't this together with deep holes, another problematical area in which

overhead crossings can at least remove that problem? Overhead crossing in which there are no piers in the river?

A Well, as I have stated we don't consider it to be a problem.

Q All right. I take it that, Dr. Morgenstern you would perhaps know, that the goudging in the Beaufort Sea has in fact been determined by field observation? Is that correct?

WITNESS MORGENSTERN: A Yes, there have been observations of scour marks.

Q Yes, it's been measured in essence. Dr. Cooper, why isn't is possible to give some assurance to your hypothesis by doing that here in the Mackenzie?

WITNESS COOPER: A Well, I should point out that subsequent to break-up, we have gone in and made rather extensive measurements in the reach upstream of Point Separation. Some extensive bed soundings and again I would like to indicate that we have found no evidence of any significant scour that could be attributed to this cause.

Q I thought you told me -- and I may have misunderstood -- that you hadn't done any measurement of channel bed gouging by upended ice. Am I now to understand that you have?

A No, what we have done is we have measured channel bed topography subsequent to the breakup of the ice on the Mackenzie River.

Q You've taken soundings and you haven't found any --

A We haven't found any inconsistencies that could be attributed to that cause. Now, I pointed out earlier that this is not conclusive. They could be filled in by that time.

Q Well now, Dr. Cooper, I take it it's perhaps obvious at this stage in the hearings, but is it not so that there is no precedent for buried pipeline crossings in the Territories or in Northern Canada?

A That there is no precedent?

Q Yes.

A Well --

Q Except for the Pointed Mountain Pipeline.

A Well, of course we had the Canol Line that crossed a number of rivers. I don't like to discuss it in terms of the Mackenzie because I believe it failed; however, I should point out that --

Q Well, let's be perfectly fair, in speaking of buried crossings, that the so-called

precedents are really three: The first is the Trans-Alaska, which hasn't been built yet.

A It's under construction.

Q Yes. So that isn't at the moment able to tell us anything about buried crossings and how they work in fact. So you wouldn't regard that at this moment as a precedent.

A I think with respect to buried crossings, for the most part we do have considerable precedent from pipelines constructed in areas further south.

Q No, but I'd like you, if I could, to restrict you to precedents in northern territories for a reason that I'll come to in a moment.

A O.K.

Q And I take it that what you have is the T.A.P., which isn't built yet. They are probably using us as a precedent.

A I don't believe so, no.

Q You have the Canol Line which (a) failed, and(b) is not there to be observed.

A Yes, the reason it failed, I might point out, is that it crossed the Mackenzie River without bearing measures to lay the pipe on the bed.

Q I'm sorry, without what?

A They didn't, to my understanding, they didn't bury the pipe.

THE COMMISSIONER: They laid it on the river bed?

A Right.

Q That was a 4-inch oil line, wasn't it?

A I believe so.

MR GENEST: That was in World War II, they were in a hurry.

A Yes.

MR. SCOTT: And the only actual precedent that has been referred to is the Pointed Mountain Pipeline.

A That's correct.

Q Have you made observations or read the literature in connection with those crossings? I know Dr. Hardy has told us something about it, but I wonder if you had--

A No, the only information in connection with those crossings that I have seen is the report that Dr. Hollingshead had.

Q I take it that the crossings, that the two crossings there are in no way unusual, that is they would be duplicated by the crossings of a number of rivers on this pipeline.

A I can't answer that, but I won't disagree with you, no.

Q No, well you don't disagree. Dr. Hardy, I take it the crossings there are in no way unusual and would be duplicated in the Mackenzie

Valley Pipeline.

WITNESS HARDY: I doubt it if the crossing of the Kotaneelee River would be duplicated on the Mackenzie Valley.

Q Why not?

A Because it's a particular type of river that is -- I don't know of any specific river on the GAGSL line that has the same characteristics.

Q Well what are the characteristics that distinguish that river from all the rivers that you're going to have to cross in the Mackenzie Valley Pipeline?

A Well, the particular hydraulics and the run-off characteristics.

Q Well, tell me what they are, what makes it different?

A Well, in terms of what happens, you see --

Q I don't want to interrupt you but we will come to what happened later. I want to know why that river is -- cannot be compared with any of the rivers in the Mackenzie Valley.

A Well, I have to compare it with the rivers that are -- that I have had experience with, personally, on the Trans-Mountain and Westcoast systems, and it has had different characteristics than the rivers that I have had experience in that area. Now the major difference is really in the runoff

characteristics in hindsight. In other words, the run-off characteristics are somewhat different than I expected they would be in the light of other rivers.

Q Well, why are the runoff characteristics for that river different than runoff characteristics that may attach to any of the rivers, or some of the rivers you have to cross in this project?

A Well, it can be due to a variety of conditions. One of them there is that it has not a particularly large drainage basin, and it originates in rather rugged topography.

Q Aren't there many rivers that have to be crossed here that exhibit that characteristic?

A Oh yes, if you like details, it's a combination of details that produce that condition.

Q Well, what I'm concerned to assert, if it's true, is that that river on the Twin Mountain, on the Pointed Mountain Line is not fundamentally different than other rivers -- not all of them but some of the rivers that you will have to cross on this particular pipeline.

A No, I don't agree with that, sir. It was of extremely rare occurrence.

Q Well, why is the river unique? What makes that river one that is, the characteristics of which are not found in this project?

A Well, there's a whole

series of factors.

Q Just tell them to me one by one, if you will.

A Well, I've given you two.

Q Well, which are they? The basin?

A The nature of the basin.

Q And you've told us that that is a characteristic that may be found on some of the rivers of the Mackenzie.

A And then there are the climatic factors.

Q Well, are those climatic factors not to be found associated with any river that will have to be crossed in this project?

A Not necessarily.

Q They may be found here --

A They might be found, yes. They could be found.

Q Any other differences?

A Then there is the vegetation characteristics.

Q Is there anything about the vegetation there that cannot be found with respect to some of the rivers in the Mackenzie Valley project?

A That's right, could be, yes.

Q Are you saying --

A And then there's the characteristic of the bed materials themselves.

Q Is there anything about those bed materials that may not --

A They can be matched somewhere else, yes.

Q They can be matched here.

A Yes.

Q Well then, wouldn't you agree with me, Dr. Hardy, that the individual characteristics of that river can be found in various rivers in the Mackenzie Valley project?

A As separate entities, yes. And yet the performance, of course, is extremely rare.

Q Well, we'll come to performance, but I take it that each of the characteristics of that river will be duplicated at one or another place in the Mackenzie Valley project.

A They may be, yes.

Q And in that sense there is nothing unusual about that river.

A That's correct.

Q Well now, when was that crossing built, the crossing of that river?

A Oh, I haven't got the precise date but I think it was four years ago, if you really want to know it accurately I could get it but I haven't got it, I haven't got it in the hotel here either.

Q And that crossing failed, I understand.

A No, it didn't fail.

Q Well, what do you mean it didn't fail?

A The pipe was never taken out of service.

Q Aha, the pipe was never moved. But wasn't the crossing a failure in the sense that--

A It depends on your definition of failure.

Q Well, of course, but wasn't the crossing a failure not because the pipeline was damaged but because very great environmental damage was done as a result of the failure, and the necessity to repair it on a number of occasions?

A The environmental damage had nothing to do with the pipeline.

Q No, but I'm putting it to you that while the crossing did not fail in the sense that the integrity of the pipe was never damaged, the crossing itself was a failure in environmental terms.

A No, not due to the pipeline. It was due to the natural conditions that would have developed whether the pipeline was there or not. The construction of the pipeline did not create the flow conditions that resulted in the environmental damage.

Q Dr. Hardy, several

reports have been made about this phenomena, isn't that correct?

A I haven't seen them.

Q I see, including government reports. Are you aware of those?

A I have not seen them.

Q And is it your assertion that the environmental damage, if such it was, that occurred there would have occurred even if no pipeline had been built?

A Yes, that's primarily correct. There may be some minor details that were affected by the existence of the pipeline, but the river running wild and the damage to the banks and the great erosive attack on the banks had nothing whatever to do with the pipeline.

Q But if there had been no pipeline there, the erosive attacks by the heavy water would have simply been allowed to occur, and no one would have bothered about it. Right?

A They would have created the same environmental damage as did occur.

Q Well, what you're telling me is that every time a bank erodes there is environmental damage.

A That's the way I look at it.

Q All right, and therefore that erosion would have occurred whether you had a

pipeline there or not. Isn't the fundamental difference that when that natural erosion occurred the company was obliged to do what it would not otherwise have done, that is to go in and make it good?

A Make the banks good?

Q Yes.

A Well, this is done, it's being done now, as a matter of fact, it may be finished, it's been done this winter but not under the instruction to re-establish the original conditions but in their own interests with the various regulatory authorities having a --

Q It's much to their credit, I'm not being critical of it.

A They're protecting the pipeline.

Q I'm simply --

A Not re-establishing the environment.

Q I'm simply saying that a phenomena of nature which occurred on that river and which could have been allowed to exist is now must be repaired by the pipeline company because the pipeline is present.

A If there is no pipeline they wouldn't be repairing it.

Q Exactly, and it's the process of repair that causes very severe environmental damage.

A The process of repair?

Q Yes, taking big heavy equipment in there.

A I don't agree with that at all, in that location. The equipment that has been taken in there is not as heavy as the equipment used to build the pipeline. Nowhere near as heavy.

Q Well, I want to read you a statement, a portion of a report. I'm not sure it's an exhibit, by E.B. Owen of the Northern Natural Resources & Environment Branch of the Department of Indian & Northern Affairs, in a paper called:

> "Observations on the right-of-way of the Pointed Mountain Gas Pipeline,"

dated February, 1975, and prepared for the environmental social Committee, Northern Pipelines Task Force on Northern Oil Development. It refers to this reparation of the erosion and it says:

> "With the apparent consent of the Fisheries and Marine Service, Environment Canada, Westcoast Transmission bulldozed some 400-500 cubic yards of gravel from a bar in the south channel of the Kotaneelee River to cover an exposed section of the pipe."

Now, is that true?

A I can't say it for certain, sir.

Q Have you any reason to doubt it?

A No reason to doubt it, no.

Q The reasoning behind granting permission to remove granular materials from what in the past has been considered to be an environmentally sensitive deposit is unclear to the writer. Were you aware that that was an environmentally sensitive area?

A I'm quite well aware of that, yes. But the bar, you see, is not a stable bar. The bars are -- they shift around and they're re-established.

Q Well, are you aware --

A In addition to that, in addition to the river bar material, you see, they also brought in shot rock, they blasted rock from a rock quarry they established to get riprapping.

Q Yes, was this nearby this environmentally sensitive area?

A It was within a mile or so, yes.

Q And isn't it true that the other crossings have necessitated the continual expenditure of money to maintain their integrity?

A The other crossings?

Q Yes.

A Which other crossings?

Q Well, I'm sorry, the other crossing, there's one other, isn't there?

A Well, it hasn't involved

continual -- there has been some maintenance on one bank.

Q But the pipe eroded on the other crossing, didn't it?

MR. GENEST: Do you mean the right-of-way, Mr. Scott?

MR. SCOTT: I'm sorry, the right-of-way, yes.

A Well, the erosion of the right-of-way, there is another problem which I have not been directly associated with, that was at the extreme north end of the line, where the erosion was into a lake there and the fisheries people were concerned about the transport of silt into that lake which apparently was a good fishing lake. There had been a lot of discussions on that as to how it could be prevented and repaired, but I am not familiar with the details of that.

Q I ask you or Dr. Cooper, can't we say that the experience of river crossings in the Northern Territories has not been a happy one?

WITNESS HARDY: No, I would not agree with that. The thing is that there were some lessons learned from that one, and you see, for example --

Q Did you take any calculated risks in preparing that river crossing?

A As far as I was concerned, sir, there was no calculated risk. I thought that was a safe crossing.

Q You proceeded with perfect assurance that there would be no problems.

A As perfect assurance as you can get with the irregularities of the climate.

Q Yours was pretty complete yesterday. I think Dr. Hollingshead has --

WITNESS HOLLINGSHEAD: I was just going to describe, I think that the second crossing that you refer to is probably the LaBiche one and the problem there was not associated with the river channel at all. It seems to me that that was an erosion problem on a slope some distance removed from the crossing.

WITNESS HARDY: It was on the valley bank, the bank was well back from the --

Q I understand that, Dr. Hollingshead, that it was a natural phenomena, but I

take it it was necessary to repair it because the pipeline ran through that area.

A Yes, I am sure it was.

Q Yes, and therefore --

WITNESS HARDY: There wasn't any repair done, sir, on that, as far as I am aware.

Q Well, this --

A Just a little local drainage done at the top of a slope.

Q Yes, was any equipment taken in to do that?

A They probably had a bulldozer in to do that work at the top.

Q Is there a road that leads to the site?

A I can't recall how they got that in there.

Q Yes, do you remember --

A It's one of the problems, to get access with equipment in there; but there are local people that have equipment.

Q Do you remember the season in the year when this work was done?

A Well, I have looked at this crossing in each of the last three years, as far as our annual inspection, and the behaviour of the south bank or the west bank, really, of the LaBiche River was largely a matter of erosion.

Q Yes.

A And this was to a considerable degree caused by the disturbance in the construction of the pipeline; but that same sort of phenomena has occurred in many other locations and has been controlled. Now at one stage when I first saw that my concern was that we were thawing permafrost, and this turned out to be not the case at all.

Q You said, Dr. Hardy, at page 2742 that the phenomenas that occurred at this river, that is the erosion and the repair problems, was not completely unusual.

A That's at the Kotaneelee River

Q Yes.

A It's also true of the LaBiche River, too.

Q Yes.

A I think I went on to say that there was -- I can think now of two other rivers on the Westcoast system that were similarly unique, if you like. We have now taken, you see, one of these as well as the Kotaneelee, the operation of re-establishing the pipeline has involved channel control. It's a design system, it's not that they've simply gone in there and patched up the pipeline or taken -- done work only to protect the pipeline. It's been done at both of those locations with the complete co-operation of the regulatory authorities.

Q Indeed, at their

insistance.

A That's not quite right. It's with complete co-operation, sir. There's no policeman standing there saying, "You have to do this."

Q Well, perhaps --

A It was a joint effort and the fisheries people in B.C. were very interested in the designs that were forthcoming.

MR. SCOTT: Perhaps, Mr. Commissioner, subject to proof, I would like to file as the next exhibit this report.

THE COMMISSIONER: That is the Owen Report?

MR. SCOTT: The Owen Report.

THE COMMISSIONER: Well, I think that subject to what you may say, Mr. Genest, it should be marked. I think Dr. Casagrande's report should be marked too.

MR. SCOTT: Yes. I was afraid to mention his name this morning, but I had that on my list.

MR. GENEST: Sir, I have some -- I know this is a problem that faces an Inquiry of this kind all the time. If there are controversial statements in these articles with which we don't agree, the stand on the record is evidence which we can't possibly challenge by cross-examination.

MR. SCOTT: No, it's subject to proof, I understand it's subject to proof; but I

think as it has been referred to, it should be put in. Now I'm handicapped because the copy I have is only some excerpted pages, and that's obviously no good. I'll have to undertake to file the full report.

MR. GENEST: Well, do I understand that you're undertaking to call the author of the report?

MR. SCOTT: It's subject to proof.

MR. GENEST: Well, I don't know what that means, Mr. Scott.

MR. SCOTT: It means that if I determine for Commission counsel staff that we wish to rely on anything that is said in that report, we obviously have to call the person who made it. If I don't, it seems to me that unless there is some particular position in respect of a government document -- and at the moment I don't think there is -- I obviously can't rely on it if I don't call the author.

THE COMMISSIONER: Well, it seems clear enough with regard to the Owen Report, having regard to what was said about Dr. Casagrande's eminence in the field of geotechnical engineering, I take it that he is a figure of great prominence along with Terzaghi and others, that his article was in a sense to be accepted in the same way as a textbook. Maybe it's time for coffee and Mr. Genest and you might think about it.

MR. SCOTT: May I make one

observation about that? I think that with the exception of Dr. Morgenstern, who proposed what I called a refinement, he didn't, I understood every panelist yesterday to accept the paragraphs that I read.

THE COMMISSIONER: Oh yes, I know that, but I was thinking that if Dr. Casagrande's article were introduced and marked as an exhibit, to what extent could I rely on anything else in that article that might be certainly of usefulness in the sense of offering some kind of background discussion of geotechnical engineering and whatever else he said there that led him to expound this statement he made about the calculated risk. Now that it seems to me is very much like a textbook, and we have always acknowledged that we can look at textbooks that are shown to be written by outstanding figures in any field.

MR. GENEST: Sir, I take it it's a matter of weight, and my problem with this kind of thing is whether or not I am then expected, once an article of that kind goes in, to -- if I don't agree with any of the material that maybe in the textbook, is there an obligation then cast upon me to take my witnesses through the textbook and say, "well, he is a very eminent man, but I disagree with his conclusion here, there and everywhere."

THE COMMISSIONER: I don't think you're obliged to do that, and certainly I should think that the only passages in Dr. Casagrande's article

that would be of any real consequence would be those that have been read. But for instance, take Dr. Terzaghi presumaby he has written in this field and presumably an article or a book that he's written might be brought forward. I understand he's dead -- I hope I'm not being --

MR. GENEST: The condition of admissibility.

THE COMMISSIONER: Well, there isn't much anybody can do about challenging anything he's said by cross-examining him, and you'd have to rely on Dr. Hardy or Dr. Morgenstern saying, "Well, despite Dr. Terzaghi's eminance we think he went wrong here."

MR. GENEST: Right, sir.

MR. SCOTT: I think I neglected to point out that not only did Dr. Morgenstern have a qualification, or I think he put it another way of looking at it, but Dr. Hardy , as I understood, didn't agree with any of the paragraphs I read.

However, the transcript will make that clear.

THE COMMISSIONER: Well, I am interested in coffee at the moment. Is there some?

(PROCEEDINGS ADJOURNED)

(PROCEEDINGS RESUMED PURSUANT TO ADJOURNMENT)

(JOURNAL OF THE SOIL MECHANICS AND FOUNDATIONS DIVISION, PROCEEDINGS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS, THE TERZAGHI LECTURE, MARKED EXHIBIT 92)

(OBSERVATIONS ON THE RIGHT-OF-WAY OF THE POINTED MOUNTAIN GAS PIPELINE, BY E.B. OWEN AND D.W. VAN EYK, MARKED EXHIBIT 93)

MR. SCOTT:
Q Dr. Hollingshead, I understand from the evidence that has been given that you have proposed from time to time on the tributary rivers that lead into the Mackenzie that you are crossing, to install various standard training works, as they may be required. And that you have made preliminary designs for some of those training works?
WITNESS HOLLINGSHEAD: A Yes, there will probably be some instances in which river training works may be required.
Q Yes, and I take it that those training works run the gamut from armouring to spurs, to dykes and so on, of the type I think you described by way of slides?
A That's possible.
Q Yes. And I also understand that it may be necessary as you come to these river crossings and see the necessity for this kind of

training work from time to time, to take these measures so that they may extend beyond the right-of-way from time to time?

A Some training works may be outside the right-of-way, that's true.

Q Yes, so you may have to build in these training works upstream, downstream and sometimes in appropriate cases, for some substantial distance even beyond the right-of-way?

A Possibly, yes.

Q When do you intend to construct these? In what season of the year?

A I haven't given that detailed consideration yet.

Q Well you would agree with me wouldn't you that these works traditionally aren't constructed in the winter when the rivers are ice choked?

A Yes, I would agree traditionally probably not in the winter.

Q Yes, and indeed if they are to be constructed in the winter you will have to get some heavy equipment in there to remove the ice from the locations at which you propose to construct the works?

A That's possible.

Q Yes, and I put it to you, that in doing that there is a risk that you will cause a substantial mess in the channel?

A I don't think if the job is done properly sir, that we would cause a substantial mess, no.

Q On the other hand if you don't perform this work in the winter, how are you going to get to the site in the summer or autumn season? You're not going to have a snow road are you?

A It seems to me that it depends upon the sort of trainning works that one has designed and how they are going to be constructed, what they are going to be constructed of, what equipment is required to do it. Some of it may be helicopter transportable, some of it may simply be constructed without any equipment whatsoever.

Q Yes, but do I understand that if these works aren't done in the winter that it will be necessary, in so far as helicopters can't assist you, to go through the bush or over the land to get to the site?

A I'm sorry, what was the question?

Q Leave aside helicopters, which is one of your options, and if this work is to be done in the non-winter season, isn't is obvious that you're not going to have a snow road?

A Yes.

Q And that you are therefore going to have to come through the bush or over the land with your heavy equipment or whatever equipment is

necessary to do this work?

A If heavy equipment is required, yes.

Q Yes, now isn't that likely to have environmental consequences of some profundity?

A Possibly.

Q Yes. The reason I asked the question is this; do I understand you to say that you have not given any consideration as to when this kind of work will be done? That is the winter on the one hand, or the summer on the other?

A We have not even really pinned down exactly where such training works may be required.

Q Yes, and therefore I take it that it follows that you haven't given any consideration as to when it will be done at those locations where it is necessary to do it?

A Not with respect to specific locations, no.

Q But not even generally, have you?

A We have not given it detailed consideration, no sir.

Q The reason I ask, is because you have presented a series of designs for this kind of work and indicated that where it is necessary these will be suitable solutions. Wouldn't you agree with me that an essential characteristic of preliminary

design work is the determination that the work can be performed?

A I am confident that the work can be performed, if required, yes sir.

Q Well, how can you be confident that the work can be performed without having given any thought to the season of the year and the consequences of one season as opposed to another at which it will be performed?

WITNESS WILLIAMS: A Mr. Scott, may I contribute to that answer?

Q Well, if it doesn't require a geotechnical answer, yes Mr. Williams, please.

A The magnitude of the situation would govern, I would think that if a situation arose where the stream bed appeared that it was going to expose the pipe, or do irreparable damage, then the maintainence work would have to be done as quickly as possible. And it would be done similarily to what we have described as repairs to a pipeline failure. If it happens in the summertime, that's when it would have to be repaired, and the consequences would be similar. And we've gone on to say that we do have the wherewithall to repair damage, resulting damage.

Q I have no doubt that the works that Dr. Hollingshead has designed and has described by way of slides, can be physically built. I am not quarrelling about that at all. I'm sure that it can be physically done. What I am concerned about Dr.

Holingshead, is if you are presenting those as design solutions, without consideration of the impact of the solutions themselves, such as appear when you have been unable to tell us when they will be constructed?

WITNESS HOLLINGSHEAD: A It seems to me that some would be constructed possibly some during the summer period. Possibly others during the winter period. And that this will depend upon site specific information and data which will be collected during the final design stage.

Q Yes, but isn't -- the reason for these works is to either protect the integrity of the pipe or to prevent some environmental damage. Isn't that so?

A By and large, yes.

Q Yes, and you have devised designs which you think as a geotechnician will solve those porblems?

A We have not devised designs, we have shown some typical designs of the sorts of things that can be used/ and might be used in certain situations. It may well prove that these typical designs if you like, that we have illustrated, may in fact not be necessary.

Q I understand that, but surely when you are developing techniques for resolving these problems, and that's the stage you are at , isn't it?

A Yes sir.

Q Yes. Surely you are obliged to consider whether the solution is going -- ie. bank works, is going to create environmental problems of its' own?

A Yes, we have given some general thought to this, and I do not see any that would create environmental damage in their own right.

Q But I take it what you are saying is, that you've formed no determination as a matter of principle as to when they should be built?

A I would say again, that I think that in most instances they would probably be done during the normal pipeline construction spread seasons, but there may be instances in which that is not appropriate.

Q Yes. Well now, let me turn to another matter. Dr. Cooper, you have outlined for the Commissioner the formula that you have utilized to predict scour in straight river situations?

WITNESS COOPER: A Yes, that's correct.

Q And you have shown how by an expansion of that formula you predict scour under jams? A modification of the formula, is that a better way?

A No, it's a completely different analogy.

Q All right. Well, let's take the first, the formula by which you predict scour.

In open water situations, lets take that example first. Would you agree with me that your formula, and I don't criticise it, I don't know enough to criticise it, but your formula is not one that is widely accepted in engineering circles?

A I would have to ask you what formula you are talking about here?

Q It's the formula that you explained to the Commissioner, I believe at the beginning of your evidence, in which you devise a factor running from, depending on the case, 1.5 to 4. And you apply that factor to measure notionally the depth of scour?

A Well, I think that that procedure rather than a formula if you like, I wouldn't agree that it is not generally accepted. There is controversy on the procedure for determining the depth that goes into the formula. I will agree on that.

Q Well, would you agree that that latter part of your formula, if I can call it that is not widely accepted in engineering circles?

A No, sir, I wouldn't.

Q No. Well are you familiar with a text edited by C.R. Neil, with articles by a number engineers, called "Guide to Bridge Hydrolics"?

A Yes sir, I am.

Q Yes. That's a respectable text, I don't put it any higher than that?

A It's a respectable text,

yes, I'll go along with that.

Q And would you agree from reading that book that your procedure is not included in that text? Although it purports to be a survey of procedures?

A To the best of my knowledge, and I would have to look through the text, nowhere in that text is there a procedure of any kind for predicting scour that is not associated with a bridge pier or a constriction of the channel.

Q Well, the chapter to which I refer is called, "Natural Scour at Uncontrolled Bridge Crossings". And you understand, do you not, uncontrolled bridge crossing to be a crossing at which there is no pier?

A That's correct, yes.

Q So what we're dealing with is scour, in a river, a bridge happens to be over it, but the bridge isn't in the river at all? When we're talking about natural scour at uncontrolled bridge crossings?

A I'd have to check precisely what Mr. Neil means by uncontrolled bridge crossings. There is probable a constriction dealt within there.

Q Well let me, I can pass on to something else. There is a special chapter that deals with constricted crossings, and the -- I'll let you review it and you can make your comments on it, but

the point I want to make, if it's correct, is that your procedure, this doesn't mean it's wrong, is not a procedure that is referred to in this text?

A Could I see that text?

Q Certainly.

Q Just before I ask you to look at it, you would agree that there are other procedures for the solution of this problem?

WITNESS COOPER: Yes, there are other procedures. However, the other procedures are not generally applicable to the types of configurations of channels that we would get. There are certainly other procedures that could be used, for example, to predict scour, where we have a definite constriction of the flow, a definite narrowing of the channel.

Q But I take it that the other procedures are different than yours. Let me put it this way, there are other engineers who would present a different procedure confronted with this problem than you have presented, in determining scour.

A In determining scour in the types of cases we're dealing with, and the types of cases I illustrated, I know of one other procedure that is very theoretical, that could be used, yes.

Q You know only of one?

A In the circumstances that we disscussed.

Q I just want to get your position so others can comment on it. You know only of one?

A Yes, in the circumstances.

Q And whose is that?

A It's a modelling procedure that has been developed at Colorado State University.

Q And that may produce different results, may it not?

A It may well produce different results, yes.

Q And I take it that before we get to the text again, that your procedure includes a co-efficient which we've described.

A That's right.

Q 1.5 to 4.

A That's correct.

Q And I put it to you that the rules for determining whether you use 1.5 or 2 or 2.5 or 3 or 4 are very vague and ill-defined.

A They're based on the decision within a much narrower range than that would be based on judgment. For example, if we were faced with a confined meander bend where the straight reach of the channel was essentially impinging on it, then we would have to make a judgment within a narrow range of say oh, 3 to 3.5, something like that, depending on the severity of attack, the height of the bank, etc.

Q And I take it that when you do that you make a personal judgment as to the selection of the co-efficient, and that involves a risk.

A It certainly involves a judgment.

Q And it involves a risk that the realities may exceed your co-efficient.

A In a sense I suppose any judgment involves a risk, in that sense you're correct.

Q Well now, will you turn to the text and I'll turn to something else? Dr. Hollingshead, would you agree with the proposition that the rate at which a river shifts its channel in the course of meandering is very hard to predict? I am talking about the rate.

WITNESS HOLLINGSHEAD: It's probably quite variable from river to river. I don't know that that's the same as saying it's difficult to predict. I think in some instances it might be relatively easy to predict.

Q I'm not asking you about whether the shifting is predictable. I'm asking you whether the rate of shift is easy or difficult to predict.

A That's what I'm talking about.

Q And what is your answer? I'm not clear.

A Well, certainly in some rivers it's probably quite easy to predict, relatively easy to predict; in others it might be less easy to predict. By and large I think we have a reasonable handle on the rate of shifting.

Q All right, and I take it that the rate, whatever it is, is variable from year

to year and from place to place in the river.

A Yes sir, yes.

Q And I take it from reading one of your reports that it is your judgment that the banks at Swimming Point crossing are stable.

A That the banks are stable. Well, they're -- what do you mean by "stable"? That they are going to remain unmoved or in the same position for the next several decades? There is no serious instability there.

Q Well, let's just read what you say. Again in this report entitled:

"Preliminary design of six major river crossings"

of August, 1974, you're the author of that, are you?

A Yes sir.

Q You say, dealing with the Swimming Point crossing, under paragraph C-channel,

"Comparison of older photographic coverage and more recent N.E.S.C.L. coverage,"

that's your own work, I take it,

"does not indicate any evidence of active migration, though no detailed measurements have been made."

A Yes.

Q Now isn't that a conclusion that in your judgment, based on photographic coverage and more recent N.E.S.C.L. coverage, that the bank there is stable?

A The evidence indicates

that the two banks are relatively stable. That's right, yes.

Q And I take it that that will be the determinant or one of the determinants in deciding how and where and at what point you're going to cross at that place.

A It's a factor, yes.

Q And it's an important factor, if you have a stable bank you can make a much more economic crossing.

A Yes sir.

Q Yes. Well, Dr. Morgenstern, I understand that -- and I may have it wrong -- that in a report of yours dated May, 1973, based on observations, you concluded that the channel there was shifting quite rapidly. Have I got that wrong, or have I got that right?

WITNESS MORGENSTERN: I think if you could read that to me, it would be better. It's sometime since I made that report.

Q I am referring to a report of May, 1973, called:

> "Some observations on slope stability at major river crossings,"

of which you and Dr. McRoberts are the authors.

A Yes sir.

Q And you say this at page 18, after referring to the observations or the data:

"Thus it is evident that some 7 1/2 miles of northward migration of the bend at Swimming Point has occurred. This migration is currently focused in the immediate proximity of the crossing site,"

and then further down:

"Thus it is possible that erosive attack may occur and the geomorphological evidence supports this view."

Was that your view at the time?

A Yes, this is based on an evaluation of the air photos at that time. We drew attention to the fact that this particular feature should be looked at in the field, and evaluated in more detail.

Q Yes, and I take it that your conclusion then was that the river channel was shifting quite rapidly at that location.

A No, the observation was by the shape of the channel it might support that the river channel was shifting rapidly, therefore we should look at this in the field. The presence of frozen ground might indicate that the channel was shifting slowly but that it was controlling the shape.

Q Well, when you said, Dr. Morgenstern,

"Thus it is evident that some 7 1/2 miles of the northward migration of the bend at Swimming Point has occurred, this migration is currently

focused in the immediate proximity of the crossing site."

Weren't you making a judgment that the crossing was shifting?

A No sir, that 7 1/2 migration or incision in the channel might well have taken 10 to 15,000 years.

We are drawing attention to a peculiar geomorphic feature and likely it did occur very slowly. Nevertheless, looking at the photograph it was our responsibility to point these things out and to direct the N.E.S. people back to the field to re-evaluate.

Q I take it then it is your conclusion that the bank at Swimming Point is stable.

A Yes.

Q Dr. Cooper, have you had an opportunity to look that up?

WITNESS COOPER: The method that's stated in here is very similar and almost identical to the method we're using. What it is is a method based on Lacey's approach to estimating the mean depth. However, they take that mean depth, and I might read from the report where it says:

"Equation 4.5 gives only an estimated mean depth across the channel section. To estimate the maximum natural scour depth, a multiplying factor must be applied,"

which is essentially or exactly what we are doing.

Q Well, isn't it fair to say, Dr. Cooper, that there are two procedures: One that is disclosed in that book, and one that is yours. They may parallel from point to point but there are two procedures that can produce different results.

A I consider them to be identical. Now, I might also point out that this procedure is, as is identified in here, applicable only to sandbed rivers.

Q All right, that may be so, but is it your proposition because others will comment on it, is it your proposition that the method you have utilized is disclosed in that text?

A The fundamentals of the method we utilized is disclosed in the text.

Q Well, we've dealt with the fundamentals. Is your procedure disclosed in that text? I mean you may have a better one, I don't know. But is your procedure disclosed in that text?

A Well, I'm not really sure how to answer that. Basically, yes, it is.

Q All right. Dr. Cooper, are you familiar with the term "avulsion" in the context of river channels?

A Evulsion, no, I'm not.

Q Avulsion.

A Avulsion?

Q Yes.

A No sir.

Q There may be some other word to describe it. I'm referring to a text, Leopold, Wolman & Millar, "Alluvial processes in Geomorphology," is the text familiar to you?

A Yes, I am familiar with many parts of it.

Q It's a standard text?

A Yes sir, in the field of geomorphology, it certainly is.

Q At page 84 at the bottom the author says this, and I'll just read it to you to see if it brings a concept to your mind that you may have been describing in some other language:

> "Major avulsions or changes in channel direction and form occur regularly, particularly in semi-arid regions and even in humid regions during catastrophic rare floods."

ARe you familiar with the process where by there are major changes in channel direction?

MR. GENEST: Mr. Commissioner, I must ask again that Mr. Scott should follow the usual procedure. He sort of reads out a paragraph, doesn't ask the witness whether he agrees with it or not. To me it's not fair to these witnesses to spring texts at them, except in the accepted way which has been developed because it is fair to the witness.

MR. SCOTT: All right, I think that's a fair comment, Mr. Commissioner, and I accept

it.

Q Does that help you understand the term "avulsion" or not?

A Yes, it does.

Q All right, now what do you understand by "avulsion"?

A Well, changes in channel course.

Q And is it fair to say that conditions favoring an avulsion or a change in the channel course, build up gradually?

A In some circumstances they may build up gradually. In some circumstances quite rapidly.

Q Yes, but in any event, regardless of the buildup, the exact time at which the channel changes its course is unpredictable.

A The exact time, yes.

Q Now, looking at the Mackenzie Delta, isn't it clear that there is a distinct possibility that there will be a change in course in that delta from the middle channel to the east channel at some time in the future?

A This is getting into the area of predicting the long-term changes within the delta. Now, I think within the channels that certainly we are crossing, we would fully anticipate whatever changes could occur.

Q Well, just so I'll be

clear, what we're talking about here, as I understand it, is a process in which there are two channels and one, and as a result of conditions, the water in one eventually moves into the other, and the first either dries up or becomes minor.

A Yes, you could certainly get a very long-term change in the delta, in the tendency of the flow to the east channel or for that matter back to the middle channel.

Q All right now, what do you say from your studies about the prospect of a change from a flow from the middle channel to the east channel?

A I would say that these changes would be very, very slow in developing.

Q Well, let me ask you this, do you predict a change of that type?

A We have not considered it to be a major factor in the designs, we don't consider, because of the time it would take, to have a major change of that nature.

Q Before we get to that, do you regard that change as a distinct possibility in the future? Leave aside time.

A Well, how far in the future?

Q No, is an examination of the river channels sufficient to enable you to conclude whether that change is in the works?

A No, I wouldn't say that we can conclude that it is in the works and it will take place, because other events within the delta may halt the process.

Q I take it that in any event, the crossing at Swimming Point makes no allowance for that possibility.

A No sir, it doesn't.

Q So that as far as Swimming Point is concerned, you've assumed that that avulsion is not going to occur within the lifetime of the pipeline.

A We certainly have not considered that the entire flow of the Mackenzie would be directed through the east channel, no.

Q And again you've made a judgment and taken a risk in setting your crossing.

A I would consider it a negligible risk.

Q All right. Have you taken the opinion of others with respect to the possibility of that avulsion within the life of the pipeline?

A Only in the respect that amongst the other members of our firm and of Northern Engineering Services we have certainly discussed in some detail the things that ought to be considered.

Q No outside opinion?

A No, no outside opinion.

Q And would you agree with me that avulsions of that type could occur on many of the crossings on the Yukon North Slope?

A I would agree that avulsions and very rapid changes in channel pattern could occur on the braided rivers on the North Slope. Not of that type, though.

Q I see.

A It is a different type.

Q But situations in which the channel changes, the principal or one of the principal changes changes.

A Yes sir.

Q And I take it that in preparing your river crossings you have not made any assessment as to whether those avulsions are likely or unlikely within the life of the pipeline?

A Well, I would say we certainly have made an assessment in that we have based in stating our methods, we simply state that they can occur and will be accounted for in the designs.

Q Yes, but I take it that in terms of placing the pipe you have not made any allowance for those possibilities on the basis that you think they are unlikely to occur, in the short-term.

A No, we've -- it's not

relevant to my way of thinking in the placement of the pipe; but we've designed the crossing or we will design the crossings on the basis that they will occur.

Q So that what is going to happen, I take it -- and tell me if I'm wrong -- is that at each of these crossings at some point a judgment will have to be made as to whether an avulsion is likely within the lifetime of the pipeline.

A I think we're talking about the same thing in the North Slope braided rivers. To my way of thinking the judgment has been made, they will happen and they'll happen on an annual basis. We get very rapid shifting of these channels.

Q Well, has the -- in each case has the, on the Yukon North Slope, has the entry of the pipe into the river channel taken account of all prospective avulsions?

A Yes, our design methods are such that we would take account of them.

Q Because you would agree with me, that if during the life of the pipeline, there is an avulsion that has not been predicted, that goes behind the sag bend, it may cause difficulties.

A It could cause difficulties, yes.

Q Not only engineering but environmental difficulties.

A I think more engineering than environmental.

Q Well, to fix the engineering ones there may be some environmental ones, would that be fair?

A It would be fair to say, yes.

THE COMMISSIONER: Has Dr. Hollingshead's report on six river crossings been marked as an exhibit? I know it must be on the list of documents provided by Arctic Gas, but for me to be able to examine it it should be marked as an exhibit.

MR. SCOTT: I don't think it has, Mr. Commissioner.

MR. GENEST: I don't believe it has either.

(DR. HOLLINGSHEAD'S REPORT MARKED EXHIBIT 94)

MR. GENEST:We'll tender it, sir.

THE COMMISSIONER: Just give it the next number, Miss Hutchison, and when Mr. Genest supplies a copy, it can be marked.

MR. SCOTT: Dr. Hollingshead, I wonder if you could describe for us with respect to let us say a 10 to 30-foot wide river on the Yukon North Slope how you propose to cross that? What are you going to do, ditch it?

WITNESS HOLLINGSHEAD: This 10 to 30-foot wide river, is that a single channel in size channel, is that one sub-channel in a --

Q One channel.

A A single channel.

Q Yes.

A The pipe would be buried in a ditch beneath the stream bed.

Q But I take it it will be ditched, will it? A ditcher will go across the river.

A Not necessarily a ditcher.

Q How will it be done then?

A It could be a back-hoe.

Q And what is going to be done with the spoil that is produced in that situation, which I take it will be piled on the ice while the work is being done?

A That's right, it would be probably piled on the ice.

Q And then what's going to be done with it later?

A Then it would be returned to the ditch over above the pipe.

Q I see, and this, I take it, to be clear is going to be done in the winter?

A It would undoubtedly be done in the winter.

Q Do you think there's any practical prospect that the repair work necessary as a result of that exercise can be done in the winter?

A The repair work?

Q Yes.

MR. GENEST: What repair work?

A Nothing has been broken yet.

MR. SCOTT: No, but I take it that after --

THE COMMISSIONER: I hope not.

MR. SCOTT: No, I don't make myself clear. You see, you speak of repair work in terms of the pipe breaking all the time, and I'm quite content that you people will be able to solve those problems. I'm interested in repair work in another context, that is repair to river banks and repair to the flow of streams and so on. Don't worry about the pipe, I'm sure that you people can handle repairing that. Is it going to be possible to affect that kind of repair, of which I'm speaking, in the winter?

A You're talking about re-building the banks?

Q Rebuilding the banks again, restoring the channel.

A Yes sir.

Q Well, what are you going to do with the ice and the snow?

A The ice will melt; the snow will disappear.

Q And it's intended that this will be done in the winter. How are you going to get through the ice and snow to do this repair work?

THE COMMISSIONER: Will you wait for the ice to melt? Will you wait for the snow to melt? Is that what you meant?

A No, no, no. I think perhaps I should let Mr. Williams -- I suspect this will come up more in the construction panel --

MR. SCOTT: I know it will, and I want to hear Mr. Williams on that, but I put it to you that in terms of presenting a design solution for these problems, you are obliged, are you not, to consider the environmental impact of the solution?

A But as I --

Q Isn't that fair?

A Yes.

Q And isn't it so that -- others may have considered it -- but that you in preparing the design haven't considered it?

A Oh, I think we have. Now I just lost you a little bit. Are we talking about the ditching, preparing the ditch to receive the pipe?

Q No, I'm satisfied that the pipe will get in the ditch all right, but as I understand from the exercise you're going to send in a ditcher or a backhoe and the stuff will be piled up on top of the ice and snow, and then will be replaced -- is that correct, Mr. Williams -- into the trench?

A It will be replaced into the trench to the original bed deposit.

Q Well now I take it that

the situation isn't just going to be left that way, is it?

MR. GENEST: What situation? I can't understand the questions, Mr. Chairman.

A I'm sorry, I'm a little lost, too.

MR. SCOTT: How are you going to repair the bank?

A The bank will be rebuilt according to the final design that is produced for that particular crossing.

Q When will it be rebuilt?

A At the time, immediately after the pipe is installed and the material has to be put back into place.

Q In the winter?

A That is correct.

Q And as a matter of implementing your design, are you satisfied that that can be done before the snow and the ice have been removed, to your final satisfaction?

A You've got to take the snow and the ice off before you can produce the ditch, presumably.

Q At the ditch area, yes.

A At the ditch area, yes. And then the pipe goes in and then the bank will be rebuilt and the ditch and the stream bed re-filled with the available material, and any question of what

happens to the snow and ice after that, it seems to me to be irrelevant.

Q All right, if that's your view. Mr. Williams, did you want to add something?

WITNESS WILLIAMS: I was wondering how this is going to be any different from tens or 20 or hundreds maybe of river crossings built in Northern Alberta and British Columbia in the wintertime?

Q It's probably not, but there are special mandates connected with this pipeline that don't attach to your other pipelines, and it's about those environmental mandates that I'm concerned to ask questions.

A Well, traditionally rivers in Northern Alberta and British Columbia are crossed in the wintertime and they are restored at the time of construction.

Q I take it, Mr. Williams, that you're not telling the Inquiry that you're going to build the kind of pipeline that you build in Southern Ontario.

WITNESS HOLLINGSHEAD: He said Northern Alberta.

Q Well, let's take Southern Ontario or Northern Ontario.

WITNESS WILLIAMS: Some of the procedures are the same.

Q Are they going to produce the same impacts with which I am familiar?

I would have thought that there was a special environmental obligation here which you willingly assumed, or assumed, and which makes you particularly conscious of these matters.

A Yes, we have outlined some special procedures that take into account environmental considerations.

Q So it's the position of Northern Engineering that it's going to be done better here, isn't it?

MR. GENEST: Better than what, Mr. Scott?

MR. SCOTT: Better than the traditional pipeline methods exhibited in Southern Canada in terms of restoring the environment.

A Special procedures will be required for the particular environment, yes.

MR. SCOTT: Excuse me one moment, Mr Chairman.

THE COMMISSIONER: Just so I understand where we're at, the comparison with pipelines in Northern Alberta or Northern B.C., however far it extends, is limited, as I understand it, by two things, first of all certainly on the North Slope of the Yukon you are within the region of continuous permafrost; and secondly, you haven't built pipelines to carry chilled gas in Northern Alberta or Northern B.C. There is no question about what I've just said, is there?

A I agree, sir, yes. But I don't think the bank restoration is contingent on the chilled pipe concept.

Q No, but bank restoration may well be affected by the fact that the bank lies within the zone of continuous permafrost. Presumably that's a much different problem than what you'd encounter in restoring a bank in a zone where there is no permafrost, or in a zone of discontinuous permafrost.

A But these Northern Alberta and British Columbia crossings that I speak about do have a substantial depth of seasonal frost at the time of construction, and certainly the frost will be deeper, but the procedures, I think, are known.

MR. SCOTT: May I just clear up a number of matters that we have in our notes?

Q First of all, Dr. Hardy on Monday, I think, Monday a week ago, made some observations about blasting of ice jams. Do I understand that no ice jams have ever been blasted on the Mackenzie River?

WITNESS HARDY: What I said, Mr. Scott, was that blasting would be considered, and this is what I pointed out yesterday.

Q Yes, well --

A And it will be considered

because every time there is an ice jam somewhere and it's causing trouble, someone suggests blasting. Now there have been all sorts of rivers in Northern Alberta and the Northwestern part of this continent where blasting has been considered and has been used with ice jams.

Q Yes. Well, the reason I asked the question is that obviously blasting in some respects may make Dr. Cooper's predictions less key than they are now, and the first question I want to ask; is anybody on the panel familiar with blasting on the Mackenzie River of ice jams? Has it ever been done?

A On the Mackenzie River?

Q Yes.

A Well, I am not familiar with any, but there is no reason to believe that it would be any different than anywhere else; and the part of the blasting technique that would come in in these considerations that I'm talking about would be that it doesn't put Dr. Cooper out of business, it's part of the game.

Q All right, well we don't want that, but I take it then we can affirm that as far as we know it has never been done on the Mackenzie River, and I think Dr. --

A I can't say that at all. The Mackenzie River is a long river and they've been having ice jams for generations.

Q You don't know --

A And there may have been some done --

Q You don't know of any, Dr. Hardy?

A But you asked me to say that there weren't any.

Q Well, I don't ask you to speak beyond your personal knowledge. Do you know of any blasting of ice jams?

A I don't know --

MR. GENEST: Oh, come on, Mr. Scott. He answered your question quite adequately.

MR. SCOTT: Dr. Hardy is fencing with me. Dr. Hardy is fencing and --

A No, I'm not fencing at all, sir.

MR. GENEST: My learned friend, Mr. Commissioner, turned a question that said, "Do you know of any blasting"?

And Dr. Hardy said, "No."

And he said, "So then there's been no blasting," which is an entirely different --

MR. SCOTT: If I did that, I apologize, I apologize to you, Dr. Hardy, as well.

Q Now --

A I'm sorry if I am not making myself clear.

Q -- do you know of any blasting of ice jams on the Mackenzie?

A I know of none, no,

Q I take it nobody else knows of any?

A Oh, I wouldn't say that at all.

(LAUGHTER)

Q Nobody else on the panel, is there anybody else on the panel who knows of blasting ice jams in the Mackenzie? I take it the answer is negative.

A Right.

Q All right, now you said, as I understood you, Dr. Hardy, that it was a matter that should be considered.

A I said it would be considered, not should; would be considered.

Q All right. Is Northern Engineering in the course of considering it?

A No, in the context that I suggested that in the evidence, sir, and as I explained a few minutes ago, it's almost an axiom that if you are faced with an ice jam that you figure was going to damage this pipeline, the people that were concerned with the protection of the pipeline would give consideration to blasting, and in that consideration there would be a great number of factors come in, and they would get experts in the field of blasting ice jams.

Q The point that concerns

me is that if it is the position that blasting of ice jams on the Mackenzie River may be considered at some point by the applicant, for whatever purpose; I want to know if any work is being done on that subject.

A Not that I know of. There is know-how, there is expertise available on this that you could go out and engage.

Q Well, my point, and perhaps Dr. Hollingshead can answer it, is if this is seriously being considered, or is likely to be considered, what studies have been done about its possibilities and about its effects?

A You're taking the existing all out of the context of the original evidence that was given, sir.

WITNESS HOLLINGSHEAD: I was just going to say we are not now considering blasting. We are not actively considering blasting,

Q And I take it that it's not -- as far as you can see -- a realistic prospect? At the moment.

A At the moment we are not looking at it as a potential solution or realistic solution to the problem.

Q Well,I'm entirely satisfied with that.

WITNESS HARDY: I must point out, Mr. Scott, though, you see in the government regulations that are being proposed, blasting is given attention

in the subjunctive mood. The subjunctive mood, sir.

Q Oh, in the subjunctive mood, I understand.

MR. GENEST: Many subjunctive blasts --

MR. SCOTT: I've got Northern Engineering Services' position on record with respect to blasting, and I'm entirely satisfied with that. I don't have to pursue something that they don't take -- that they are not actively considering.

Well now Dr. Hollingshead, let me just ask one or two questions about the crossing at Swimming Point.

You've decided that there should be a twin crossing there as I understand it?

WITNESS HOLLINGSHEAD: A

We have recommended a dual crossing.

Q Yes, and one of the pipes will be in the position that the original pipe was going to be in, is that correct?

A Yes, sir.

Q And the other, I understand will be on the north side of the original location?

A It's downstream, sir. That's northeast.

Q Did you give any consideration for reasons that we will have to deal with later, to placing it on the other side of the original line? That is, on the south side?

A I believe that was looked at at least, the reach of the river was studied but this was a very preliminary study, and it would certainly bear a further looking in the final design stages.

Q Yes, Were you aware that the northernmost crossing, the additional line to the north downstream, goes through an area that some at least regard as recreationally and archaeologically

important at the Holmes River?

A No, I wasn't aware of that sir.

Q No. Well now, in Section 8A page 6 of the application, and I don't know who should deal with this, except that it has to do with the rivers. The applicant claims to have developed special techniques for crossing "beaded streams." And we don't seem to have heard anything about that, if I understood what people were talking about.

Where is the evidence of that technique, or the attempt to develop one? Are there reports that deal with the special techniques that you have developed to cross beaded streams?

A We showed very simple schematic diagrams of typical crossings in the Exhibits.

Q Yes, but I --

A This included one which would accommodate a so-called beaded stream.

Q Yes. The promise of the application to me at least was that a special technique had been developed to deal with beaded streams. Is that correct?

A I don't think that there is anything special about it.

Q You are just going to cross that stream, the way you cross all the others? It seems to hold out a prospect of --

MR. GENEST: Could I have a

reference to that, Mr. Scott?

MR. SCOTT: Yes, it's at page number 6.

THE COMMISSIONER: That's Exhibit 54? Is that Exhibit 54? And that's, what is it again, 8 what, Mr. Scott?

MR. SCOTT: It's 8A.

THE COMMISSIONER: 8A, page --

MR. GENEST: Tab one description.

MR. SCOTT: I don't have the tabs, I just have loose sheets. Page 6.

I should perhaps read it. "An example of an environmental problem", it's the third paragraph --

THE COMMISSIONER: Yes, that's right.

MR. SCOTT: --"which was solved as a result of such interdisciplinary work, involved the beaded stream, which appeared to be of little engineering consequence during the initial route location work".

Q Now, I take it, stopping there, that what that means is that the beaded stream didn't present any engineering problems that were unusual? Is that correct?

WITNESS HOLLINGSHEAD: A I think that's fair to say, yes.

Q The passage goes on, "such

streams however, are often used by Arctic grayling for critical spawning and summer feeding activity. It was therefore necessary for the engineers to develop techniques for crossing these streams so that their ability to support fish life was not impaired."

MR. GENEST: Where does 'special' appear?

MR. SCOTT: Well it doesn't, I put that --

MR. GENEST: Well again Mr. Commissioner I must insist that if my friend is putting statements to the witnesses he should quote them accurately.

MR. SCOTT: Q All right, let me ask this question Dr. Hollingshead? Is there anything unusual or special about the techniques that you are going to use to cross beaded streams?

A Not particularly I don't think, except that the location would be such that it would be between beads presumably.

Q No, but this sentence says, " it was therefore necessary for the engineers to develop techniques for crossing these streams."

WITNESS CLARK: A Perhaps I could add to that Mr. Scott?

Q Thank you Dr. Clark.

A I recall a discussion with our fish consultants where they pointed out to us that the beaded streams were used in some instances for

over-wintering, or for a migratory path.

Q Yes.

A We had been unaware of that, because they are rather small streams in many instances you can stip over them or get beyond them, but they are quite deep. They are characterized by, in areas where ice has melted out to form what looks like a bead. When this was pointed out to us at that time, we felt that there were designs that could maintain a flow through those areas.

We have since expanded on our analysis to determine whether or not the ice would freeze to the bottom, at the location of the pipe. We have found that a very small flow is required to keep that open. These were convective studies that were made by Dr. Harlin and some of them are referred to in the responses to questions in the PAGG group, but not specifically to beaded streams.

There was also, we have discussed in previous evidence, some of the techniques that we could use to maintain flow in a gravel bed where there is significant bed flow. So that these would be treated on an adhoc basis.

Q Dr. Clark, I don't want to take up the time of the Commission, but can you direct me to the place in your application or in your material, where you set out the technique that you have developed that will be used at beaded streams?

A Not in the application,

no. Other than the typical drawing that Dr. Hollingshead referred to.

MR. GENEST: It seems to me that that was discussed Mr. Commissioner, in chief, that very problem, the forming of an ice barrier at a stream where downstream fish need a continuing water supply, and we had quite a discussion as to the methods which would be used.

MR. SCOTT: We haven't been able to find in the transcript as I understand it, any technique that was developed for beaded streams. Perhaps if there is one, without wasting any time, Dr. Hollingshead on a later occasion can let me know what the technique is, and where it can be found, sot that we can examine it. I may have overlooked it, but--

Q Well now, one other matter if that matter can be left that way, is that in his examination by Mr. Bayly, Mr. Dau on the last panel indicated that it would take a few days, to one week to restore service in case of a damaged river crossing.

The dual river crossing report of July, 1974, indicates does it not Dr. Hollingshead that the worst case failure would be between 30 days and 150 days?

WITNESS HOLLINGSHEAD: A Yes, sir.

Q Yes, is there any way of extrapolating an average case that isn't a worst

case, but isn't the best case?

WITNESS WILLIAMS: A Mr. Scott, are you sure that he was referring to river crossings in that--

Q I thought he was. I just didn't think he intended to say that, and I just wanted to clarify with this panel.

A I don't think he did. I think he was referring to a failure on dry land.

Q I am now told that it may have been a typrographical error, but I take it that if he was referring to a river crossing, this panels' view is that the worst case is 30 days to 150 days, and I take it the best case is substantially more than a week?

A At river crossings?

Q At river crossings. What do you think the mean time for repairing a river crossing, not the worst but not the best would be?

A We have dealt with this in one of the responses to the Assessment Group where we suggest that possibly a temporary line would be installed. It would depend on the river; a temporary crossing could probably be installed and back into service in as short as time as a week, but again depending on the time of year and what the river was doing. But, and then the permanent repair would take much longer. Putting in a permanent repair, a replacement of the whole river section would essentially take as

long as the original installation. So I don't think there's a real definitive answer to your question. It would depend on circumstances.

Q Now let me turn to one other matter. Dr. Cooper, I take it that in designing any river related structure one of the inputs to your design is what is called the design flow?

WITNESS COOPER: A That is correct.

Q Yes.

A You are referring to training works? Or a buried pipeline crossing?

Q Either one?

A Well, of course there is different use of design flow in either case, but go on.

Q And I take it, that , if I can put it in laymens' language, the design flow is an estimate depending upon which standard you use of the volume of water that passes a given point at a given time?

A The rate of which; if you add the rate to that, yes.

Q All right. Is it the rate or the rate and the volume?

A Well, it's the rate at which that volume passes.

Q I see. Would it be correct to say that both the Assessment Group and a large consulting firm have expressed doubts about the

adequacy of the design flow figure that you have assumed?

A I'm aware of concerns that have been expressed about the application of the design flow data that we are using. In some cases this was a misunderstanding, in some cases -- I'll go into the misunderstanding I think, just to clarify it.

The one instance I'm thinking of was on the design on the Firth River, whereby our selection of a design flow was the flow in a sub-channel which naturally would be considerably less than the river in total was carrying, at that time.

I believe there's been some concern expressed as to the adequacy of the data in general that we are using. And I would like to point out that basically this is data, and that we are ourselves reassessing the most severe flows that we will use for different types of design.

Q Well, I take it that in one of your reports which has been referred to this morning, you recommend that the design discharge for river crossings should be what is called the "One Hundred Year Flood"?

A This was recommended in one of my reports for preliminary design done some years ago, several years ago.

Q Well is that design flow basis on which your studies have been made? Is

that what you are using?

A No, not in all cases, no. That's what we are using on the Mackenzie River.

Q That's what you are using on the Mackenzie River?

A Yes.

Q What are you using in other cases?

A We're using an estimate of a severe, or an extreme flow that is based on an analysis of maximum recorded flows. It has no statistical significance, that estimate, but in practice we find it very useful for design.

Q Well let's take the "hundred Year Flood", first, and I wonder if you could explain, I was going to say to the Commissioner, but perhaps to me, what that is? Because that is used on the Mackenzie isn't it?

A Yes, that has been used on the preliminary designs on the Mackenzie.

Q That's what you are using on the Mackenzie?

A What we mean by "a hundred year flow" is the flow that has a statistical probability of recurrance once in a hundred years. The way we arrive at this number is to analyse existing stream flow records and do a frequency or statistical analysis on the maximum flow in each of the years throughout the period of record.

Usually it's necessary to extrapolate this analysis since we very seldom have flow records that extend to a hundred years. In the case of the Mackenzie it's in the order of 25 years that we have these records. In that way we come up with a flood discharge of a frequency recurrance of one in a hundred years.

THE COMMISSIONER: Well, the concern being I take it that once in a hundred year flood might occur within the lifetime of the pipeline?

A Yes, of course there is a concern of this, and there is a very real probability associated with it. However, I should like to point out that in the final design of these crossings we will, particularly the Mackenzie River crossing where fortunately we do have a fair amount of flow data, we would look at these with respect to predicting scour on the basis of even higher flows occuring.

Now I think it's also important to realize, and I hope I don't get too technical here, that the flood frequency curve on the Mackenzie River is very flat or unresponsive. This is due to the rather constant input from Great Slave Lake. Now, in pratical terms what I mean by that is the difference, the relative difference say between a 50 year flood and a 100 year flood, or the relative difference betweeen say a 100 year flood and a flood of even rarer occurence, is low.

In other words, there is not

that much difference in the flow, because of this lake input. It's low in comparison to rivers such as the Liard or the Peace etcetera.

Q Well, Dr. Cooper, how m any years of stream flow observations are necessary at a river site to make a reliable estimate of the 100 year flood, within let's say a 20% range?

WITNESS COOPER: I would say for a river the type that we're dealing with, with the Mackenzie, it's something in the order of 25 or 30 years would be considered adequate. For a river that exhibited greater changes in these flows you would need possibly 35 to 50 years.

Q Well, I put it to you that to say that with a river that exhibits greater changes you really beg the question, don't you, because you're trying to predict from 35 years' experience what the experience over 100 years will be?

A What it might be.

Q What it might be.

A That's correct.

Q Well, would you disagree with an engineer who asserted that in order to determine a reliable estimate for the 100- year flood you would have to have observations pretty close, if not in excess, of 100 years?

A Again this depends, sir, on your degree of reliability. Now, on the Mackenzie River --

Q Well, I'm concerned about risk, that's why I asked this.

A -- on the Mackenzie River,

I have to emphasize that we do have a lot of things working for us, primarily the rather constant inflow from Great Slave Lake, which forms a significant part of that flow.

THE COMMISSIONER: Did you say Great Bear Lake?

A Great Slave Lake. Great Bear Lake also adds to the rather well-tamed behaviour of the flow.

Q A minute ago in answer to my question I thought you said Great Bear, but you meant Great Slave?

A I meant Great Slave.

MR. SCOTT: Well, just so I'll understand for later purposes, is it your proposition that you can obtain a reliable estimate of the 100-year flood after 25 years of observation on the Mackenzie Valley? On the Mackenzie River?

A Yes, it's my opinion that 25 years on the Mackenzie River is adequate. On a lot of other rivers I'd say no to that.

Q What's required on other rivers that are within the ambit of this project?

A I would say 35 to 50.

Q I see. Well now let's see if I understand what that means. Let's assume that a river crossing of the Mackenzie, as it will be, I gather, is designed to 100 year flood level, the design flow. Let's assume that, all right?

A Fine.

Q And let us also assume -- it may not be the case -- that any greater flood would damage the crossing.

A I agree with you, it would not be the case but --

Q Well, let's assume it.

A Fine.

Q That's what we're talking about, and let's assume that the crossing has a life of 25 years.

A Fine.

Q What are the chances numerically that the river crossing will be damaged on those assumptions within 25 years?

A If all your assumptions are correct, the probability of damage would be significant. I don't have the exact figure with me, but it is calculable.

Q Would it be roughly 22%?

A That could be right.

Q And I take it that that is the risk that potentially at least is at stake if one uses the 100 year figure on the Mackenzie?

A Accepting all of your assumptions, which I do not accept.

Q All right, but even if you don't, I take it the assumption you don't accept

is the assumption that a greater flood will necessarily damage the pipe?

A That's correct. In establishing a design for the pipeline, we would -- the minimum we would do, is try and estimate, even though the reliability of the estimate would be somewhat uncertain, we would estimate what the maximum flood that could occur, and we would evaluate what this would do to scour.

Q Well --

A So in answer to your question, the total safety of the design is not predicated on the occurrence or the exceedance of a 100 year flood, no.

Q But would you agree with me that I produced the figure 22%, and you say, "Well, that's based on your assumptions, and one of your assumptions is that the worst flood in excess of the 100 year flood will damage the pipe." You don't buy that. That's why you say 22% realistically is too high?

A Oh yes.

Q All right. Now would you agree that the realistic risk would be, let us say, 10%?

A No sir, much, much lower than that.

Q Well, what do you think the realistic risk on this basis is for those river

crossings?

A I cannnot place a number on it. We're involving judgment here. All I can state the risk in, is in qualitative terms and it would be extremely small.

Q Well now, on the other hand what we've been talking about is the risk that results from a flow in excess of the 100 year limit?

A Could you state that again?

Q No, what we've been talking about in trying to fix this risk to your river crossings, is what would happen if the flow exceeded the 100 year figure?

A Yes.

Q Well now, I put it to you, you and I don't agree on those figures perhaps, but I put it to you that there are a lot of other factors apart from flow that can lead to the damage of a river crossing, such as slope failure on the approaches to the river, or an ice jam?

A These are to some extent independent. Certainly the ice jam, in the case of the ice jam, you would need a combination of an ice jam and the very severe or extreme flow, to cause damage.

Q Well, wouldn't you agree with me that whatever the risk that results, or however you calculate the risk from the excess flow beyond the

100 year limit, the risk is increased by the possibility of damage from other causes, such as bank failure or ice jams or what have you?

A I'd have to go back and examine my statistics, because these are independent events, to some extent.

Q But any one of them can damage the integrity of a river crossing?

A Conceivably, yes.

Q Well, I put it to you in short that there is, I make no criticism of it, it may be solveable, but there is a measurable risk attaching to these river crossings, leaving out environmental considerations?

A I would say that there is an element of risk; a measurable one, no.

Q Well, would you agree with me that in a report to Northern Engineering Services,Shawinigan Engineering criticized the choice of the 100 year flood that you made?

A The choice of the 100 year flood?

Q Yes.

MR. GENEST: Mr. Scott, could we have the exact quotation, please?

MR. SCOTT: It's the report of the Shawinigan Engineering Co. Ltd., I don't have the cover page so I don't have the date for it, but I can find it, at page 30 of that report in commenting

on the criteria developed by T. Blench & Associates in March, 1973, and in particular commenting on design flow analysis or assumptions, the authors say:

> "The approaches used for design flood estimations to date could be challenged for being too classical and not taking full advantage of modern computational procedures. It is suggested that analyses similar to the one conducted for Section 51 be carried out for several rivers to determine whether more refined work would be of value."

And then to give meaning to that you have to return to the Section 5. Did you understand that? Perhaps I misunderstood that.

A Their --

Q Have you read that report?

A No, I haven't, sir. Could you read that section again? There was one point in it I don't think I did understand.

Q

> "The approaches used for design flood estimations to date could be challenged for being too classical and not taking full advantage of modern computational procedures. It is suggested that analyses similar to the one conducted for Section 51 be carried out for several rivers to determine whether more refined work would be of value."

A And do you have Section 51?

Q I'm not sure that I have it here. In 4.3 and 51 the authors say this:

"The important river engineering considerations pertaining to buried river crossings are identified. Of hydrological importance are the criteria for design discharge selection. The critical condition is assumed to be the 1:100 peak discharge,"

and that's the 100 year flood, is it?

A Yes.

Q But no justification is given for this choice of risk, and then on the following page, table 1 overleaf, compares flood estimates from the various sources, which are a number of other reports.

"It is noteworthy that Blench's estimates tend to be about half those of the others."

Now I understood that to be an assertion that the estimates on which the 100 year flood was chosen were one-half the estimates that others had relied on, Do you understand the observation in the same way I do?

A I think I can comment on it, and in many respects I agree. He is -- or they are speaking of the design of river crossings in general. Now, the project is undertaking to re-evaluate --

Q I'm sorry, I didn't hear

what you last said?

A The project, to my understanding, is undertaking to re-evaluate its data on the maximum flows that would be considered in the design. We have to keep in mind, of course, that in some cases these maximum flows may not be critical to design. It may be some other flow, and we have to think of that particularly in regard to scour, as we have to look at the maximum scour that can occur in the entire range of flows that can develop in a river. But I believe the type of analysis you're -- or the report is getting at, is being undertaken right now to generate this data, and it will be examined in the final design. But we're talking about data here.

Q Yes, but I take it that that data affects the -- for example, the place where the pipe enters the river, where it bends?

A No, not significantly. There are several aspects of the design it definitely would affect. It would definitely affect the design of training structures and riprap. This is, of course, the primary influence it would have.

Q Is it at least conceivable then that you may retreat from these design flow figures as you get further work done?

A Re--

Q well, I shouldn't say "retreat".

A The actual numbers that are

shown on the preliminary design?

Q Is it possible that as you get to final design you may develop another design flow criteria that produces a different formula than one in 100 years?

A I think it is quite possible that the final designs and the descriptions of those designs would include comments that -- to the effect that, flows much in excess of this have been examined.

Q Are you familiar -- I'm sure you are -- with the concept of the standard project flood?

A Yes sir, I am.

Q I take it that that's a more conservative concept than the one, in 100 years?

A They are not comparable. I've been involved with meetings, in meetings with the corps of engineers when we were discussing matters concerning design floods and there is really not a way of drawing a comparison, an exact comparison between a standard project flood and a --

Q Well, perhaps you could explain for me what the standard project flood is, what that standard is?

A It's rather arbitrary. The standard project flood is, I believe, defined as, a flood that is somewhat less than what they also refer -- I've got to describe a maximum probable flood

to begin with. Maximum probable flood assumes the worst possible storm conditions in a watershed, and on that basis a computation of the resulting flood would take place. The standard project flood assumes a storm that is somewhat less, by I believe it's 40 to 60% less, or 40 to 60% of the maximum probable storm, and the computation is based on that.

Q Yes, but what's the return period of the standard project flood?

A There is no return period associated with it. In some instances they have, that I know of, where they have compared predictions it was very close to one in 100 year flood. In most instances I will admit it's higher.

Q In most instances it's higher and I take it that in my terms that means more conservative?

A That's correct, yes.

Q And indeed, it is the standard project flood as I understand it, is the recommended design flood for sort of intermediate sized dams?

A Yes, where there is a possibility of risk to human life.

Q Yes. Well now, do I understand that the Trans-Alaska Pipeline river crossings are designed to withstand the standard project flood?

A They are, although having been involved in that there are a couple of points I'd like to describe. First of all, the --

Q Could I interrupt you just for a moment? Is it generally speaking so that on the T.A.P. project the standard project flood has been utilized?

A Yes, it has.

Q All right, and I take it that you participated in the design of that project.

A Yes sir.

Q Yes. Well now, and that design is more conservative than the design in the terms in which I used "conservative", than the design that is contemplated for the Mackenzie Valley project.

A With respect to the floods that are being used, the only -- it would not be more conservative in regard to scour depth.

Q Well, let's talk this way. It minimizes or reduces the risk of damage because it's a higher standard.

A Yes, but the standard in all instances that I can think of does not come

into the prediction of scour depth.

Q All right now, in any event that is the standard that is being used on the Trans-Alaska and we know the standard that is being used on the Mackenzie Valley proposal. Now you had some comments you wanted to make.

A Well, I tell you I think I've made the comment that I wanted to, is that although the pipeline is being designed in many instances for the standard project flood, where this value has a bearing is in matters like the height of bridge decks or the height of the pipeline where they've got an aerial crossing, because with flows like this your water surface is higher. When we make on that project computations of scour depth, in all instances I can think of we have found that the bank full condition or something slightly higher than that would be more critical for scour. So although many of the structures are being designed on the basis of the standard project flood, the scour computations --

Q Well, let me see if I understand. Why are you using one formula in Alaska and another in the Mackenzie Valley? Is it government interference or something? Why?

A This was at the point in time when we came onto the project this was part of the -- to my understanding -- of the environmental impact statement, that was agreed upon some number of years ago and it was the terms of reference under which

we worked.

Q Yes, to put it another way, weren't you told by some governmental agency that on the T.A.P. line you would design to the standard project flood?

A I believe essentially that that is true.

Q And that's what you were told?

A Yes.

Q Well now in question 37 in Northern Engineering's response to question 37 in the Assessment Group's Report, you have determined a design flow for the Firth River on the basis of a relation between the channel width and the flow in the channel. Have I got that correct? Do you want to get the response?

MR. GENEST: Question 37.

MR. SCOTT: The response to question 37.

Q Are you aware of any data that would justify applying such a formula to one of the channels in the braided gravel bed rivers unlain by permafrost?

MR. GENEST: What formula are you talking about?

MR. SCOTT: The formula referred to in the response to question 37.

MR. GENEST: With reference to

the Firth River crossing?

MR. SCOTT: Yes.

A I'd like to point out that the rivers we're talking about at the time these flows would occur would certainly not be underlain by permafrost at the shallow depth that it would affect the river flow.

Q Well, how do you know that?

A On the basis of drill hole data that we have examined on braided rivers in Alaska, and I believe some in Canada.

Q Well, you haven't drilled the Firth, have you?

A No sir, we haven't.

Q How do you know about the Firth?

A Well, in the particular case of the Firth, I'd have to say we're extrapolating data from Northern Alaska.

Q So you're taking a bore hole that exists in Northern Alaska and assuming that if you did a bore hole in the Firth River you'd get the same result?

A For the purpose of preliminary design, yes.

Q What is the return period of that flow at the Firth River?

A I think I'd better give

an explanation to that.

Q You can certainly give some to me.

A The design procedure that we're using for a braided river does not consider the flow that the entire river would carry. We must keep in mind that we probably have, if we take a cross-section of that very wide braided river, we're probably dealing with maybe half a dozen or a dozen sub-channels.

Now, as I mentioned in the direct evidence, the procedure involved selecting the largest sub-channel within a significant reach both upstream and downstream of the crossing, we would then assume some very severe conditions that sub-channel could meet with another sub-channel of the same dimensions at a rather abrupt and unfavorable angle, directly over the pipeline. This would result in a scour hole developing downstream of that confluence. O.K., the problem then is to obtain a discharge that this sub-channel is carrying, but not what the river it's carrying. That discharge that we'd be designing a sub-channel on is probably 20 or 30% of what the river would be carrying at the same time.

Q Well --

A So there's no real frequency. The discharge we're talking about here can occur quite frequently.

Q So aren't we talking therefore about a design flow on, for example, the Firth

a braided river, in the area from two to ten years?

A Yes, it might even occur, I think ten years would be high. We would get bank flow conditions probably more frequently than that.

Q Now, how do you calculate the risk not merely to the integrity of the pipe but to the environment that is inherent in choosing a design flow criteria that is of that range?

A Simply by stating that it's our belief that flows of much greater magnitude would present a lesser scour hazard. What we're doing here is predicting -- or is taking the flow we believe to be the most severe with regard to scour, and that in this case is not the very extreme flow.

MR. SCOTT: Mr. Commissioner, I'm moving onto some other topic. Do you want me to begin? It's about five to one.

THE COMMISSIONER: No, I don't. That's my answer to your question.

MR. SCOTT: I'm meeting with various counsel tonight, Mr. Commissioner, and we will bear in mind your suggestion of yesterday afternoon.

THE COMMISSIONER: All right, we'll adjourn until nine o'clock tomorrow morning then.

(PROCEEDINGS ADJOURNED TO APRIL 9, 1975)

MACKENZIE VALLEY PIPELINE INQUIRY

IN THE MATTER OF AN APPLICATION BY CANADIAN ARCTIC GAS PIPELINE LIMITED FOR A RIGHT-OF-WAY THAT MIGHT BE GRANTED ACROSS CROWN LANDS WITHIN THE YUKON TERRITORY AND THE NORTHWEST TERRITORIES FOR THE PURPOSE OF THE PROPOSED MACKENZIE VALLEY PIPELINE

and

IN THE MATTER OF THE SOCIAL, ENVIRONMENTAL AND ECONOMIC IMPACT REGIONALLY OF THE CONSTRUCTION, OPERATION AND SUBSEQUENT ABANDONMENT OF THE ABOVE PROPOSED PIPELINE

(Before the Honourable Mr. Justice Berger, Commissioner)

Yellowknife, N.W.T.

April 9, 1975.

PROCEEDINGS AT INQUIRY

VOLUME XXVI

ALLWEST REPORTING LTD.

APPEARANCES:

Mr. Ian G. Scott, Q.C. Mr. Stephen T. Goudge, Mr. Alick Ryder and Mr. Ian Roland	for Mackenzie Valley Pipeline Inquiry;
Mr. Pierre Genest, Q.C. Mr. Jack Marshall, Mr. Darryl Carter and Mr. John Steeves	for Canadian Arctic Gas Pipeline Limited;
Mr. Reginald Gibbs, Q.C. Mr. Alan Hollingworth	for Foothills Pipelines Ltd.;
Mr. Russell Anthony, and Prof. Alastair Lucas	for Canadian Arctic Resources Committee;
Mr. Glen W. Bell and Mr. Gerry Sutton	For Northwest Territories Indian Brotherhood and Metis Association of the Northwest Territories;
Miss Lesley Lane	for Inuit Tapirisat of Canada and The Committee for Original Peoples' Entitlement;
Mr. Ron Veale and Mr. Allen Lueck,	for Council for Yukon Indians
Mr. Carson H. Templeton,	for Environm ental Protection Board;
Mr. David Reesor,	for Northwest Territories Association of Municipalities;
Mr. Murray Sigler,	for Northwest Territories Chamber of Commerce.

I N D E X

Yellowknife, N.W.T.

April 9, 1975.

(PROCEEDINGS RESUMED PURSUANT TO ADJOURNMENT)

MR. SCOTT: Mr. Commissioner, I'd like to suggest to you, and I think I have the agreement of counsel on this, if you please, that we should sit tomorrow afternoon from 2 until 4:30 in an effort to complete this panel. Counsel have agreed that we should also sit an additional period next week, and I think what we would like to do, if I recall our discussions last night, accurately, is to assess the appropriate time for an extra sitting early in the week.

Some counsel are concerned that the corridor phase which is contemplated by the Inquiry Commission staff, should take place not following Phase 4 but earlier in the proceedings, that is following Phase 1, and there are things that counsel wish to say both for and against this proposition, and we therefore would like you to ask -- we would like to ask you to sit on Tuesday next at two o'clock in order to deal with that single question, that is the staging of the corridor phase. I think I have the agreement of counsel with respect to that procedure and that time and place, if it suits you.

THE COMMISSIONER: All right.

MR. SCOTT: As a result of the, I have two matters that relate to the Aklavik Community Hearing that should be dealt with, to make the record complete. The first is a letter has been

received from the Commissioner of the Northwest Territories dated April 8, 1975, and it reads:

"Dear Justice Berger:

It has been brought to my attention that during the latter part of this past week some questions have been raised concerning the attitude of my government, the Government of the Northwest Territories, towards the Mackenzie Valley Pipeline Inquiry. I have stated publicly both in the south and here in the north my support for the Inquiry.

As you know, it is my view that the Inquiry being held under your direction is of great significance to the future of the Northwest Territories. For this reason the Government of the Northwest Territories is anxious to extend support wherever possible to you and your staff, in the work of the Inquiry Commission and in its hearings.

It is extremely regrettable, therefore, that during the last few weeks there have been a misunderstanding develop with regard to our position toward the Inquiry, and particularly with regard to the extent to which our employees would be encouraged to participate in its hearings. The intent of any correspondence to our staff and the subject of their participation in the hearings was to ensure that they would be aware that any views they expressed except where they touch directly upon their

responsibilities with the Territorial Government, should not be interpreted as the views of the Territorial Government. This folbwed requests from our staff for our direction in this regard. Unfortunately, this intent was not clearly communicated in our correspondence, and a certain amount of misunderstanding resulted. It became necessary for us to send one of our senior officers to Aklavik to speak with our employees and provide them with our assurance that the Territorial Government fully supported their rights as individuals to testify before the Inquiry held within that community. I understand that this was satisfactory in clarifying our position as far as the Aklavik hearings were concerned.

In order to ensure that there can be no further misunderstanding of our position with regard to the Territorial Government employees testifying before the Inquiry, I have asked that our telexes of March 27th and April 2nd which dealt with this subject and which gave rise to the misunderstanding that took place be withdrawn.

Our employees are now being advised to this effect. Having said this I would sincerely suggest that our staffs meet as soon as convenient for the purpose of working out an acceptable arrangement with reference to facilitating the appearance of public servants

before your Inquiry.

Equally unfortunate, in my view, was the statement from us that any misunderstanding took place as a result of the failure of your staff to keep you completely informed. Although the events at the time and the problems of communication with Aklavik led us to draw this conclusion, subsequent discussion and a closer examination of the facts indicate that this was not the case. We regret any embarrassment that this may have caused either you or your staff. I trust this letter will be of assistance in clarifying the position of the Territorial Government towards the participation of our employees in Inquiry hearings.

In addition, you have my assurance that we continue to attach a great deal of value to the responsibilities you've assumed and are anxious to co-operate with you in any way possible to ensure the success of the Inquiry.

Yours sincerely,

'S.M. HODGSON'

Commissioner."

Mr. Commissioner, there is -- there was also received a letter from a resident of Aklavik that in the ordinary course would have been read at the Aklavik Community Hearing. Through an oversight, it was not read, and so that the record will be complete, I would like to follow the practice adopted at the community hearing, and read it to you so that the record of the Aklavik community hearing will be complete, and then file it as Exhibit C-9. C-9 refers to the exhibit process that has been established for community hearing exhibits.

I am unable to read the name of the author of the letter. Miss Hutchinson would be able to do that, but she is a nurse at the Aklavik Nursing Station and she writes to you dated April the 4th:

> "Sir, in looking at the sociological impact of this proposed pipeline, one has to look at the impact of change. With change comes adjustment, not only of the caribou herds or hunters, but of the hunters' families themselves. Adjustment is progress, but is progress a dependency? Change has come to this and other settlements in the delta, but not necessarily progression. Daily social pressures increase on the families and individuals as a result. The oil companies increase employment, but this increases pressure. Many families are splitting and drifting apart. Father no longer hunts on the land but goes out to oil jobs, leaving wives

and children to fend for weeks at a time. Who do they turn to? Excess money is earned, father returns -- what to do with this excess? Government supplies services and housing, so money is spent on liquor as there is time for parties, but little time to know and grow with the family. Sixty percent of total care is alcohol based at times.

Then there is the father who tries to maintain his family from the land, but animals are retreating so one travels further to trap and hunt. School is in the settlement, so mother stays behind. Father feels frustration as he can't be with his family. Trapping is becoming less and less, so frustration increases. This frustration is brought home, leads to disagreement and wives feel tension to work to keep up with the bills. There again, children are left to fend. This also brings problems, so what does the child see? Progression, no, only a feeling of aloneness, no place to turn.

If this is what it was like for parents who once would laugh and learn together and now drift apart due to circumstances beyond their control, what will the future hold for them, not knowing the ways? Our patient load increases, and drug dependency increases, something which was totally alien a few years back. Where do we go from here? More drugs and more disease, diseases never seen before are becoming

prevalent such as high blood pressure. Instead of T.B./it is now V.D. and D.T.'s. I only see change as a passer-by, but in this settlement one can't help but feel the frustration in trying to counsel a helpless but inevitable situation.

Sincerely -- "

and the letter is signed. And it's signed Nurse Parker. I would tender that as Exhibit C-9.

(LETTER FROM NURSE PARKER IN AKLAVIK MARKED AS EXHIBIT C-9)

THE COMMISSIONER: Mr. Waddell, I think these are students who have come in, and you might just assist them to find any vacant chairs if they are going to stay for any length of time, they might as well be comfortable.

MR. GENEST: Mr. Commissioner, before Mr. Scott commences, I had made a promise yesterday about some information with regard to the east of Fort Simpson route, and I find that we are still missing some dates, and I'm going to ask for your indulgence so that we can present a total package, rather than have it go in piecemeal, and if I can put that off for a few days, perhaps -- as I understand it, there will be cross-examination directed to those issues of route selection when the construction panel comes back, and perhaps I'll have that for you and my friends before that panel comes back.

THE COMMISSIONER: All right.

That seems to be agreeable to everyone.

CROSS-EXAMINATION BY MR. SCOTT, CONTINUED:

Q Dr. Cooper, I promised last night that I had no more questions for you. I'm sorry to say that I have one or two.

I refer to an answer that Dr. Clark gave at page 2364 of the transcript at line 17, actually beginning at line 9. Referring to crossing of the Bear River and the Mackenzie in particular, -- 2364. Question,

"Now has Arctic Gas carried out tests to determine whether those river beds are free of permafrost so far as the levels of the river beds that we are concerned with go?

"A Yes sir, we have conducted drilling in the beds at the Peel River, the Swimming Point crossing, the Point Separation crossing and the Great Bear Crossing.

"Q And those are free of permafrost?

"A Yes, within the depths that we explored, which is below the depth to which the pipeline would be buried.

Either for you or Dr. Clark, I rather got the impression from that question and answer that it was being asserted that the river crossings had been drilled and had been drilled below the depth to which the pipeline would be buried, and that it was on that basis that it was concluded that there was no permafrost. Am I correct or am I mistaken about that?

WITNESS HOLLINGSHEAD: Yes, I think I can speak to that. These holes -- test holes were drilled in those channels with the exception of Point Separation crossing, the test holes did extent to below the pipeline depth. Unfortunately, I think at Point Separation the holes terminate just above pipeline burial depth. But in each instance there certainly was proved that in fact there was no permafrost beneath the channels.

Q Well, if we can take them one by one. I take it that the Point Separation drilling does not go below the depth at which the pipeline will be buried, that's your answer with respect to that crossing, is it?

A I think so, as the preliminary designs show it, yes.

Q Now, dealing with the Fort Simpson amendment, I am advised that two of the crossings -- the Swimming Point crossing and the Fort Simpson crossing -- aren't drilled at all insofar as the alignment sheets indicate.

A The Swimming Point crossing has been drilled.

Q Well, there are going to be two crossings at Swimming Point. Are you saying both of them have been drilled or only one of them has been drilled?

A only the first proposed crossing was drilled; I don't think there are any test holes on the suggested twin or second crossing there, no.

Q I take it that that drilling at Fort Simpson at Swimming Point shows, is in fact a drilling that is on the bank rather than in the bed of the channel.

A There were some shallow holes put down through the bench which at times is under water, and therefore considered part of the channel.

Q Well, hae you got handy the profile and plan view of the Mackenzie River crossing at Swimming Point?

A I missed the first part of that question.

Q Have you got before you or can you get before you the profile and plan view -

MR. GENEST: Is that the design drawings?

MR. SCOTT: The Fort Simpson

alignment sheets and design drawings. So much for the mesmerizing quality of my questions and answers.

THE COMMISSIONER: What page is that?

MR. SCOTT: It's page 1-A-0232-1001. It's the second last in the book.

MR. GENEST: In the Fort Simpson route?

MR. SCOTT: Yes.

Q Well now, Dr. Hollingshead, could you look at the profile in the top left-hand corner, I think it's on the centre line profile. Do you see that?

A Yes sir.

Q Now would I be right in assuming first of all that that profile shows one of these deep holes we were talking about in another context?

A It shows the presence of a scour hole, yes.

Q Is that one of the unidentified deep holes that Dr. Cooper and I were discussing yesterday?

A No, I would not say it was an unidentified hole.

Q Well now, I take it that there are two drill holes that are shown on that profile.

A Yes sir.

Q One of them, the one on the left, is not below the pipeline. Is that correct?

A Yes, in fact it is below the pipeline.

Q It's not below the deepest point of the pipe.

A It's not below the deepest point of the pipeline.

Q And the one on the right, however, is, isn't it?

A Yes sir.

Q And I take it that the one on the right, however, is on the right east bank?

A It is.

Q And that there is no drilling in the hole or in the channel?

A On the contrary, if you look at the other two profiles, that is of the right bank and left bank respectively, you will see that in fact there are test holes indicated there which are on the flanks, if you like, of that hole, which indicate unfrozen material.

Q Yes, but I take it that there is nothing in the hole.

A Well, there doesn't appear to be one at the bottom of the hole.

Q In your judgment, is that adequate drilling for the design of a crossing at that point?

A At this stage of the design process, sir, I would think it is quite adequate.

Q I take it inherent in that answer is the assumption that more drilling will have to be done.

A That's possible.

Q Yes. I take it the drill holes that are shown on the centre line profile show that they contain frozen material.

A That's right.

Q Well, how is it possible to determine from those drill holes that there is no permafrost below the level of the pipe?

A It is the additional test holes which I refer to which give us that indication.

Q The additional holes you're talking about are shown first of all on the right bank profile, is that correct?

A Yes, Sir.

Q And on the left bank profile immediately above it?

A Yes, sir.

Q And I take it that neither of those drill holes go below the base of the pipe?

A In fact, one does sir.

Q I'm sorry.

A In fact, several of them do.

I think if it's helpful, it might also be pointed out that the mean or average annual temperature of the water in the channel there is approximately 4 degrees Centigrade, plus or minus, or Celsius, and that combined with the test hole information that you have before you would certainly indicate I think, to most people, that the chance of finding frozen ground beneath the deepest portion of that channel is highly unlikely.

Q Well perhaps I haven't made myself clear. I understood from the answer that was read, that a drill hole in the channel at this point, or adjacent to it, had revealed that there was no permafrost in the bed of the river. Now, just so I'll understand, will you point out to me the drill hole that you rely on to establish that point?

A I would suggest that the

hole shown at station 35 plus 30 possibly would establish that.

Q Are you referring to the right bank profile?

A Yes, sir.

Q Isn't the trouble with that drill hole, first of all that it's pretty close to the bank and in the second place, it's not below the depth of the pipe?

A It is indeed below the depth of the pipe --

Q I'm sorry, I must be misreading. It's below the depth of the pipe at the place where the drill occurs, but it's not below the depth of the pipe in bed of the river, is it?

A That is correct. However, the indication from those test holes on the right bank, plus our knowledge of the temperature of the water and the flow of the water in the channel, would certainly would lead one to conclude that there is no, indeed no permafrost beneath the deeper portion of the channel.

Q I understand well that there may be other considerations such as water temperature that leads you to your conclusion, but I'm trying to pursue the question of whether there is any drill hole that shows that below the deepest point of this pipe in this channel, there is no permafrost. Now, do I understand that the answer to that is yes or no? I'm not clear.

A As far as I'm aware, I don't

think there has been a hole put down through the deepest point in the hole.

Q And what we're talking about is the deepest point in the river channel or basin at which the pipe will be laid?

A Of the hole --

Q Yes.

A -- in which the pipe is laid.

Q And therefore, at this crossing at least, there is no drill hole which shows us the condition of the soil below that point?

A We have some indication from other data, not necessarily from the test holes shown here --

Q Could we deal just with drill holes, for the moment? I understand that you may have other evidence --

A Well --

Q -- but I'm trying to deal with the evidence that was led by your counsel, Mr. Genest, that there were drill holes that established this point, and I -- do I understand now that there is not a drill hole that is drilled below the requisite level at that point?

A At the bottom of the hole, probably not.

Q All right. Well, would it be fair to say then, that your conclusion that there is no permafrost below the lowest point of the pipe at

that crossing is not founded on drill hole data, but is founded on other considerations?

A No, I don't think that's a fair statement.

Q Are there any other drill holes that you refer to?

A I have a feeling there may well be, but I can't put my finger on exactly where they appear. I think perhaps Dr. Clark wants to add a word.

Q Yes.

THE COMMISSIONER: Well excuse me, Dr. Clark, wouldn't they be on this drawing?

WITNESS HOLLINGSHEAD: Not necessarily, sir. Some of this has been done recently.

WITNESS CLARK: There was drilling carried out at that site last year, I believe in -- during the winter off the ice. It was the type of drilling done, however, with a rig that didn't recover samples. It was specifically directed to check for permafrost, and one determines that by drilling resistance. It was a flush type rig, so we don't have the same type of soil description as we get from the type of rig that recovers samples.

There were quite a number of holes put down at this crossing, as I recall, and there are no logs, but they did confirm our original impression that there was no permafrost there.

I can undertake, Mr.Scott, to provide the location of those test holes. They were recorded, but I can't recall them from memory.

MR. SCOTT:

Q Yes, my only concern is that if there are other drill holes on which you rely for this point, I would be grateful if you could identify them in due course, obviously not today.

A Yes, I would like to emphasize though, there is no soil log as such because it was not possible to identify specifically the soil type. It was possible to determine whether or not the soil was frozen.

Q Thank you.

Now Dr. Cooper, if the holes that were shown on that drawing were one of the holes in the delta of unknown origin, about which we were talking yesterday, I asked you to assume that for the moment; if it were, first of all, it would be a hole that would be of a depth that would be consistent with those other holes that we were discussing in the channels.

WITNESS COOPER: I'm sorry, I don't understand that question.

Q You and I were talking yesterday about holes of unknown origin that have appeared in the delta channel?

A Yes.

Q I take it that this hole or the dip in the channel that is shown on the diagram before you, is consistent with the shape of one of those holes that you've seen from time to time in the delta?

A Well the location and depth of this hole of course is consistent with open channel hydraulics.

Q Yes, but it's consistent also, is it not, with being one of the holes that we were discussing yesterday?

A No, there is really not that much, nothing unusual about it.

Q Well, let me just review. You posited yesterday a theory that holes of unknown origin in the delta channel might be caused by the melting of ground ice.

A That would be one hypothesis, yes.

Q And if that hypothesis were correct, it would illustrate that there was permafrost perhaps in the course of melting, but that there was permafrost below the bed of the river.

A That in the course of melting sometime in the past, in the distance past, there was, yes.

Q Well, you couldn't judge whether it all melted, could you? Without an extensive drill.

A The best knowledge we have on it now, based on drilling not only in this location, indicates that under channels such as this if there is permafrost, it's at quite a deep depth.

Q Now, Dr. Cooper, if you'd look at the centre line profile that is called "Downstream crossing", do you see that?

A Yes sir.

Q Yes. Now I understood you to say yesterday in dealing with upended ice cakes that they wouldn't create a very great problem because

the dimension of the channels usually meant that the deepest point was in the centre.

A That the deepest point is some distance from the bank.

Q Yes, and that was your rationalization for the proposition that ice cakes would not do any substantial damage.

A Not entirely, no. The -- a part of that rationalization is that the depth itself would prevent gouging of the bed.

Q I take it that this diagram shows that the deepest point of the channel is in fact adjacent to the bank.

A Yes, it is several hundred feet.

Q Yes, and the detail on the following page shows a similar configuration with a depth, not in the centre of the channel but adjacent to the bank.

A Yes, some several hundred feet.

Q Well, isn't that a case in which your rationalization in support of your conclusions about the effect of up-ended ice cakes runs into some kind of difficulty?

A No, I don't really think so. We would expect that we would have, if you like, some gouging attack on that slope.

Q Which slope are you

talking about?

A What sheet is this here, the Mackenzie, the Fort Simpson?

Q Yes.

A O.K., we would have to possibly expect some gouging attack on the slope, let's say on the right bank. However, the -- you have to realize the vertical exaggeration on this drawing and look at the vertical cover on the pipe, and we're talking in terms of eight feet of possible gouging. What is the vertical cover in there?

Q It says ten feet, I think, if I read it correctly.

A Yes, it's about 30 feet, I believe, on that slope. Now, at the deepest point on the river, at the deepest point on the river we have to realize that these ice flows are floating. They maybe up-ended but essentially they will be floating in some 40 or 50 feet of water at that time, so there is essentially no possibility of gouging occurring at that deepest point. Yes, you could get gouging attack on the slope, though.

Q Well, would you look at the last drawing in the book, which is the next page?

A That's the one we've got.

Q Well then we're looking at the same one?

A Yes.

Q Well, isn't there a minimum cover there of ten feet?

A That's at the deepest point, I believe. It's in that order, yes.

WITNESS HOLLINGSHEAD: The design as it's shown indicates a depth of burial of something in the order of 30 to 40 feet, and it would not be less than 10. I think that there are other factors which come in here as well. When I gave the figure yesterday of an estimate of the maximum possible depth of gouging by direct contact of ice flows on the bed, we were assuming the worst possible conditions that is a soft sandy material, and a maximum possible size of ice flow. In fact, the banks of the Mackenzie at this location are rather armoured with boulders, etc.

Q Well, we can read the diagram, but I don't understand why you say that the cover is 30 to 40 feet when I see the figure "10" down here. Now it maybe that I don't understand what that refers to.

A Because it's shown as 30 to 40 feet.

Q Well, I may not understand, what are the meaning of the words:

"Minimum vertical cover, 10 feet,"

which I see on that drawing?

WITNESS COOPER:

A Well, the minimum vertical cover would be from the deepest point in the

channel as shown on that drawing; but in respect to scouring by ice flows, we have to realize that that could occur only at the -- or that the size of flow that could scour the bed or could gouge the bed, if you like, is such that it would not -- it's small enough so that the flow size when it was up-ended, it wouldn't even touch the bed here, it would be floating.

Q Well, let me ask you this just so I'll be sure I understand. The words,

"Minimum vertical cover, 10 feet,"

appear and then there are arrows that show the point at which that minimum cover exists, I presume.

WITNESS HOLLINGSHEAD: Maybe it would help, Mr. Scott, if I suggested that probably those words need not exist at all there.

Q I'm sorry, go ahead.

A They are really not necessary.

Q Well, they may not be necessary, but I read them to indicate the minimum cover that will be placed over the pipe on that drawing which is a representation of what you intend to do at that crossing. Am I mistaken?

A Yes sir.

Q Well, is the mistake mine or is it yours?

A It's probably my error in leaving those words on there. It is an additional

qualification or restriction, if you wish, that is simply unnecessary in this instance.

Q Well, do I understand that it should therefore read:

"Minimum vertical cover, 30 feet."?

A I don't recall exactly what the minimum depth of cover there is, over that portion of the pipeline.

Q Well, I'm unable to proceed with this line in that state of the drawing. I'll just leave it and come to something else.

THE COMMISSIONER: Before you do that, Dr. Hollingshead, we're looking at a diagram of the crossing just south-east of Fort Simpson, are we?

A It's about five miles upstream of Fort Simpson on the Mackenzie, sir.

Q Yes. Well now, the pipeline is buried beneath the river bed and the drawings show us the configuration of the river bed and beneath the river bed itself we see the pipe. Now what is the distance between the bottommost point of the river bed and the pipe?

A It's approximately ten feet, sir, at the lowest point in the channel there. The distance between the lowest point in the channel and the top of the encased pipe is about ten feet. The depth of burial of the pipe, the elevation of the pipe, has been established on the basis of the scour

calculations or predictions that were made, and that has established that level of the pipe, and it happened that that falls about ten feet below the lowest point in the existing bed, as it now is, that portion of the channel. As it -- the unfortunate thing about these drawings is that they are very much an exaggerated vertical scale so that in addition to those scour computations the additional recommendations that were made were that there should be, let us say, a minimum of ten-foot vertical cover and a minimum of 40-foot lateral cover as the pipe comes up the bank from that point. These have been carried over to the design drawings, but the actual profile, if you like, and the actual recommendations of where any specific point on the pipe should be with respect to the channel cross-section you know, shown in true scale, would indicate to you that in fact over that portion of the cross-section where we referred to a minimum vertical cover of ten feet as a minimum that should certainly be applied, in fact the burial depth is of the order of 30 feet, sir.

But this would only show up most clearly on a true scale, a true scale cross-section.

WITNESS COOPER: I think that possibly some confusion exists, because I think weare trying to describe the amount of cover that would be at the -- over the region where you could get ice gouging, sir.

Q Yes, I understand that, and your point as I take it, is that the gouging is more likely to occur in the proximity of the banks of the river, rather than in the centre of the main channel?

A That is correct.

Q All right, I understand that, but assuming that the lowest point, in terms of elevation of the river bed is somewhere in the middle of the channel, and it appears to be, at least looking at the centre line profile of the upstream crossing, you have only ten feet of cover there?

A You are looking at the drawing on the right, sir?

Q Yes.

A At the centre, I think it's closer to 20 feet cover by that scale.

MR. SCOTT:

Q Dr. Cooper, are you referring to the downstream crossing?

A I'm not sure what crossing we're on any more.

WITNESS HOLLINGSHEAD: Well, I was looking at the downstream crossing.

THE COMMISSIONER: I think this is not as complicated as it sometimes appears to be. Your argument is, your conclusions are, your professional opinion is that the danger of scour is greater in the proximity of the banks of the river crossing?

WITNESS COOPER: Now, we are talking about ice gouging.

Q Ice Gouging.

A Okay. The danger of gouging is greatest in the proximity of the banks. When we get into depth like we are talking about and even in the deepest portion of the channel as it now exists, we're talking about depths of in the order of 40 feet, which the depth of flow there is greater than the size of the ice cake that could gouge, and this ice cake is floating, so it can't possibly cut the bottom.

Q Yes, really I follow these things. It was just the mathematics over the last five or ten minutes that threw me off course.

A It threw me off a little bit too.

MR. SCOTT: Well I'm not going to pretend that I understand it.

Q Well now Dr. Cooper, if you look at sheet 1003, which is two before that, Point Separation the centre line profile upstream crossing, do you see that in the bottom left hand corner?

A Yes.

Q Well don't you have the same problem there?

A That's in the bottom corner?

Q Yes.

A Bottom left?

Q The deepest part is near the shore, right?

A That's correct.

Q And in this case, we have sandy soil in the bed of the river, don't we?

A That's correct.

Q Which is the optimum kind in terms of gouging?

A That's correct.

Q Well now, don't you have the same problem there that there may not be adequate cover to prevent gouging?

A Well, in the area again, where gouging can occur, and that is on the slope and fairly high up on that slope on the right side, we've got much more than I believe 14 feet of cover.

Q Yes.

A Or 15 feet of cover that's shown. If you measure vertically on that slope.

Q Well just so I'll be clear, if it's possible, do I understand that when you say there is a minimum coverage of a certain amount on the drawing, that you in fact contemplate that there will be more than the minimum? Is that what you're

telling us?
A In terms of the preliminary design what is shown here, we say 15 feet of cover at the bottom, but if you -- when we apply the design on the slope and have it 40 feet laterally into the bank on that slope that's coming up, in fact on the slope we would have something in the order of 20 or 25 feet of cover. Not right at the bottom, but then gouging can't occur right at the bottom. It's too deep.
Q Well let me turn to something else that relates to the Swimming Point crossing. I gather from reading the transcript, I don't have a note of it in front of me at the moment, that you will be -- or the company will be excavating a trench across the river to install the pipe and that the trench will bein the order of 30 feet? I'm sorry, I'm talking about -- I'm sorry, it's Point Separation I'm talking about, not Swimming Point. Have you got Point Separation in your mind?
A Yes.
Q I understand that thereis going to be a trench dug across the river that will be to a depth of 30 feet --
A And in some places greater.
Q And in some places greater?
A Based on the preliminary design.
Q Yes. And I take it that the trench will be dredged in relatively fine sand?

A I think Dr. Hollingshead can answer this better, it's getting into construction.

Q Very well, yes.

WITNESS HOLLINGSHEAD:

A Yes, I think the data there shows it's sand bed.

Q Yes. And I take it that in order to dig a trench in that sand bed at that location, you will need a side slope of one in six?

A I doubt it would be that flat.

Q Well what do you think is required?

A Probably something in the order of 4 to 1, three to one.

Q Yes. Dr. Morgenstern, would you be satisfied with that underwater?

WITNESS MORGENSTERN: Yes.

THE COMMISSIONER: Just before we go any further, tell me what that means?

MR. SCOTT:

Q Would you explain, Dr. Hollingshead, what one in four --

WITNESS HOLLINGSHEAD:

A Four horizontally to one vertically.

THE COMMISSIONER: So the trench at Point Separation would begin at the bottom of the river bed and would extend downwards 30 feet into the river bed. What would be its width, taking into

account the slope on each side, on the four to one ratio?

A Well it's likely going to be probably 20 feet wide at the base and the better part of 300 feet, I suppose wide, at the top. Between 250 to 300 feet.

MR. SCOTT:

Q Well would your -- I'm sorry, sir, anything?

What I'm trying to do is calculate the volume of sand to be removed.

There are two crossings there. Would the volume be two, being for two crossings, times 2,000 being the length twice, times 900, being the area?

A We had -- we actually had calculated, based on these preliminary designs, excavated volumes. I'm just trying to recall what those figures were. It seems to me it was in the order of a third of a million cubic yards.

THE COMMISSIONER: And that would be --

MR. SCOTT: A third of a million or three million?

A No, it seems to me it was certainly less than a million cubic yards. Oh, for the two crossings --

Q Yes.

A -- if the two crossings put in at the same time, it probably would be of the

order of a million cubic yards.

THE COMMISSIONER:

Q So two trenches at Point Separation for two pipes?

A Yes sir.

Q Brings you to a total volume of what?

A The two combined, we are probably talking in terms of a million cubic yards.

MR. SCOTT:

Q Well how do I get three million? You take two first of all, and then you take 2,000 and multiply it, being the length of -- or the width of the river twice --

A I'm just trying to recall what our actual figures were. We took a number of cross-sections through each of those.

WITNESS MORGENSTERN: Mr. Scott, could you inquire whether our units were in cubic feet? Dr. Hollingshead is quoting cubic yards.

MR. SCOTT:

Q We're quoting cubic yards too, Dr. Morgenstern.

WITNESS COOPER:

We did this calculation for each crossing, and it seems to me in the first one before the second crossing was drawn up, that the first one was something in the order of a half a million cubic yards of material.

Now, the second one, the way it is shown here in this very preliminary sketch is undoubtedly greater than that, so that the combined

total of the two is probably certainly in excess of a million cubic yards.

Q Well, because there is a difference between us, can we work out what the formula is and then we can get some independent assessor to do the mathematics?

Dr. Clark, you look ready to --

DR. CLARK:

A I haven't got my reliable slide rule here. Someone has said, Dr. Cooper has said 30 feet deep, that's ten yards. Approximately 300 yards wide. 300 feet wide, that's a hundred yards.

Q Stopping right there, is it not wider than 300 feet?

A The width at the top, I'm looking a t the excavated trench.

Q Yes.

A Well, even if you assume that was square and not like this, this gives you a dimension 10 yards deep, 100 yards wide; if the width of the river is then 700 yards or 2,000 feet, for a complete square would only be 700,000 yards. That's 10 x 100 x 700.

WITNESS HOLLINGSHEAD: I'm sorry, I think we're under-estimating some of the dimensions there a little bit.

THE COMMISSIONER: I wonder if this is a mathematics class that came in here?

A I've done just a quick calculation on excavating a rectangular shape 10 yards deep, 100 yards wide, that's 1,000 square yards in area, by 700 yards in length.

MR. SCOTT: Well, the problem, I think, has to do with the length.

A I took the length as 2,100 feet, or 700 yards.

WITNESS HOLLINGSHEAD: Closer to 4,000 feet.

MR. GENEST: Why don't we deprive these gentlemen of their coffee, sir, and have them work it out over the coffee break?

MR. SCOTT: Well, may I leave that, may I leave the mathematics? There's obviously a dispute that I for one have no intention of resolving and simply ask you to state your formula for calculating the amount of fill removed for the purposes of the record, at the two trenches, how you would calculate the volume.

A The volume is calculated by taking a number of cross-sections of the --

Q Could we just deal with this cross-section? Or with this crossing.

A Yes, if you will let me finish.

Q I'm sorry.

A A number of the cross-sections along the pipeline trench, taking into account the bed topography that we had, and the pipe parallel elevations and the suggested side slopes of 3 to 1 or 4 to 1, a series of cross-sectional areas were computed from one bank over to the other, and these areas multiplied by the length and then divided by 27 to give you the volume in cubic yards.

Q And Dr. Clark, what is your best estimate at the moment of the two?

WITNESS CLARK: About 3 quarters of a million yards per crossing. If you draw a rectangle and then put in that rectangle the shape of the trench, you can approximate it by saying that the trench is about half of the rectangle.

Q So that --

A The 700,000 yards that I get by that, by taking the whole rectangle over half of the width, is not too far off.

Q And double that would be, let us say, one million four, one million five.

A For the both.

Q Yes. Well now, when this trench is dug, what's going to be done with that fill?

A Les, do you want to talk on construction?

WITNESS WILLIAMS: The excavated material in the river channel would be deposited downstream of the crossing. If some was required for construction of pads, construction areas on the bank to fabricate the pipe to pull it into the crossing, some of that excavated material could or would be used for that purpose.

Q well, can you give me an example of a unit that would occupy one million five hundred cubic yards, what sort of dimensions are we talking of?

A This material is not all going to stay in place downstream of the crossing. Some of it is going to move farther down.

Q Well, we'll deal with what happens with it, if we may, in a moment. I'd like to get some sense of what are we talking about? Are we talking about a large quarry, or a small dam,

or in terms of volume, what is one million 500 cubic yards?

WITNESS HOLLINGSHEAD: Probably the easiest way to visualize it is these diagrams that we have in front of us. We've just calculated or shown roughly the dimensions of the excavation and it seems to me that those dimensions are the ones that you're looking for, are they not?

Q Well, those are the dimensions. I'm trying to make, if I can, for my own limited mathematical capacity, an analogy to some kind of ditch or hole to which I'd be familiar. Is a small dam an appropriate analogy?

A Small is a pretty relative word, sir.

Q Well, be more specific, if you can.

A A small dam.

Q And I take it that the excavation that -- Mr. Williams, did you have an example that you were going to give me to make it clear?

WITNESS WILLIAMS: I was just going to suggest rather than a dam, a submerged weir.

Q You're beyond my experience.

WITNESS HOLLINGSHEAD:
A Well, I hope that you weren't suggesting that or taking my response to indicate this material that was being deposited downstream

was going to extend up above water level and create a dam on the Mackenzie. That wasn't what I was thinking.

Q You're way ahead of me in your responses to questions I haven't asked, Dr. Hollingshead. First of all, I take it it would be two or three times the volume size of this hotel.

MR. GENEST: Have you measured this hotel, sir?

A I don't know.

MR. SCOTT: All right.

Q And I take it that that fill is going to be placed in the channel on the downstream side. Is that correct?

A Yes sir.

Q Well now has anybody on the panel given any consideration to the effects of doing that with respect to this river, and its life?

A I was going to say we have given some thought to this, and that isn't the only scheme, the only alternative.

Q Well, that's the alternative that you set out in your application, isn't it? In your application, the construction plan book at page 49 you say -- and I'm -- procedure "A", dealing with -- which is the procedure stipulated for the Mackenzie River crossing at Point Separation, you say:

"Spoil will be cast beside the trench on the downstream side."

Now is that what you're going to do, or is it not?

A That is one possibility, Mr. Scott, and I might point out that the exhibit, those words that you refer to, were written prior to the preparation of this dual design, and certainly what was in mind at that time was the downstream crossing and there we're looking at something in the order of three-quarters of a million cubic yards, which probably would have been for the most part placed on the channel bed downstream.

Q Well, do I understand that as a result of the twinning, you're not going to do this at Point Separation, you're going to do something else?

A It's possible.

Q Well --

WITNESS HARDY: I think, Mr. Scott, you should realize that there's nothing unique in this particular crossing from the point of view of the excavation, except the length of the crossing, and you're going to have a little deeper burial than you have at some other places; but these crossings are going in across the Fraser River, for example, you see. There have been two put in the Lower Fraser in recent -- the last couple of years, one was in last year, and there is a contractor's choice in how he makes the excavation. It's possible, you see, to dredge the sort of hole that you're talking about, and I think you should not misunderstand us, that when we say, a three or four to one slope, that that is precisely what will

happen. This is one of the intangibles that you cannot predict accurately beforehand what will happen.

I get asked this question very frequently by dredging contractors, and that may be much steeper, you see.

Q The point that I am anxious to make is not about the inability of engineers to do this. I have every confidence that you can do this dreding satisfactorily. I would like to know when it will be possible for us to determine what you intend to do at Point Separation with this large volume of earth so that we can then begin to assess the impact of what you propose to do?

A What I was hoping you would take from my explanation, Mr. Scott, was that we're tending to exaggerate the situation that we're talking about here in relation to what is done every few months on other major rivers in British Columbia, and the fact, you see, that we may have 700,000 or 1.4 million yards in the two crossings, what we should be concerned with is how much excavation have you got per yard of width of crossing.

Q Well --

A And where does that go?

Q -- Mr. Commissioner, I am really, I suppose, asking for some guidance from Mr. Genest. I put the question to this panel about the impact of the proposal that they have set forth in their application. Their response to my question is,

"Well, we may not do that. We may do something else."

I wonder when it will be possible to know whether the proposal contained in the application is going to be followed, or whether some other procedure is going to be adopted, because there is no point wasting any time as far as the participants are concerned, analyzing the effect of dumping a million and a half cubic yards of fill downstream, if we're going to be told in the last analysis, "Well, that isn't going to be done, something else is going to be done."

A I don't think, Mr. Scott, there's any suggestion that we're trying to evade the question.

Q No, no.

A What I'm trying to point out to you is that you're grossly exaggerating the difficulty of the problem, and now there are people that can give evidence to the question as you've just put it, what will happen, you see, and when will it be done and what the effect of that is, and that involves environmentalists, I think.

MR. GENEST: Well, I think, Mr. Scott, what you're after, is what it is exactly we intend to do with this 1 1/2 million.

MR. SCOTT: Precisely.

MR. GENEST: Our application says we intend to deposit it down the river. It's been pointed out that since the application was drawn up, the quantities have doubled, and what is our present

stand? The only thing, I can take that under advisement and let you know very quickly.

MR. SCOTT: I asked the question because I am instructed that under the appropriate laws or ordinance, that volume of fill cannot be placed in the Fraser River, and I'm concerned about --

MR. GENEST: In what river?

MR. SCOTT: In the Fraser River.

MR. GENEST: Oh.

MR. SCOTT: And I want to ask some questions about putting it in the Mackenzie River, if that is the course that is to be adopted.

WITNESS HARDY: Again, sir, you are referring to total volume instead of volume per yard of width, and it makes a tremendous difference, and I would say you can get permission to place that quantity per yard in the Fraser at some times, not any day of the week.

THE COMMISSIONER: Well, Dr. Hardy, can I ask you about the Fraser? The crossings that were trenched in the Fraser, were they carried out -- you said, I think you said the lower Fraser -- and unless I lost something, there wouldn't be any ice, would there?

A Well you see, you can adjust one way to do it. This is -- on the Mackenzie, they probably would be placed in on the ice. At Hope, there's one at Hope in B.C., that probably wouldn't be placed on the ice. There is also one in the last year or two at Shelley, which is up in the Prince George area, and that could be placed on the ice.

But the fact is though, you see, that from -- it really in a sense is irrelevant as to whether they place it on the ice or whether they don't, although the mechanics of what happens to the excavation can be quite different. If you are using, if you are digging in the open water, why then it's -- you deposit it and it's not a matter of what we do with it, it's what that river will do with it, amongst other things, you see, and these things are predictable. This is not a unique practice is the point I am trying to make.

Q Well --

A But there is no precise answer in every foot you will get the same result if you do the same thing.

Q You are saying to us that this is a vast quantity of earth, but the river is a very wide river, is that -- that's the point you've been emphasizing with Mr. Scott?

A That's right. We should be talking about the amount of earth we have to handle per yard, because you see on the Fraser, on the lower Fraser, there have been crossings put in where the

cover is 60 feet, more than we are talking about in some of these cases here. And in that case, you see the amount of spoil per yard of crossing is -- would be more than would be here.

MR. SCOTT: Well, Mr. Commissioner, I would like to defer that until Mr. Genest has been able to get us the alternatives that may be adopted at this crossing. I don't want to pursue the examination of a possibility that may not be now intended.

Could I come to one other matter, Dr. Cooper? In the evidence, there are two terms that have been used in place to place. One is fossil flood plain, and the other is alluvial terrace. Do I understand that those terms refer to the same thing, in your judgment?

WITNESS COOPER:

A Yes, they do in my judgment.

Q And that therefore, both a fossil flood plain and alluvial terrace is a river built surface that lies above normal flood levels, but could conceivably be flooded under extreme conditions?

A Some of them could, yes.

Q Yes. Well now, dealing with what has been described in the evidence as active flood plain -- you're familiar with that term?

A Yes sir.

Q And do I understand correctly that that is a river built surface that is flooded or partially flooded when the flow in a river

exceeds what are called "bank full conditions"?

A Yes, that would be basically correct.

Q Now I would like, with some trepidation, ask some questions of frost heave. Dr. Slusarchuk, would I be correct in listing the following four factors as being the factors, that give rise to the phenomena known as frost heave? First of all, unfrozen soil; in the second place, a freezing temperature; in the third place, a susceptible soil, and in the fourth place, the presence of water?

WITNESS SLUSARCHUK:

A Yes sir, that would.

Q Well now, I understand from other evidence that has been given, that about 200 miles of the pipeline will be buried in unfrozen -- in a discontinuous area in which there is unfrozen soil?

A Yes, sir.

Q And that that runs roughly from the Willowlake River entry down to the border at Alberta?

A Yes,sir.

Q I take it that because a great deal of money has been spent on the dealing with the problem of frost heave, that Northern Engineering Services regard it, if unsolved, as a serious problem. Would that be fair?

A If unsolved, as a serious problem?

Q Yes. If there were no -- if you had not devised a solution to the problems of frost heave, those problems would be a serious impediment to the construction of the pipeline?

A Yes sir, I think that's a fair statement.

Q And can you tell me, just in point form, what the consequences of the failure to solve the problem of frost heave would be? What would happen if you hadn't been able to solve this problem, in point form?

A Well if we couldn't solve the frost heave problem, then it would tend to heave the pipe and possibly overstrain it and burst it, that's a possibility.

Q Yes. Would, short of bursting the pipe, would there also be a vastly increased maintenance problem if frost heave were not resolved?

A I'm not quite sure I am following you, sir. What part of -- what maintenance are you referring to here?

Q Keeping the pipe in place.

A Well if you hadn't solved the problem, how are you going to know what to do in your maintenance? I'm not quite sure what you are referring to there.

Q Let me put it this way, then. I think your observation is quite correct, if you haven't solved the problem, you don't know how to repair it. Would it be fair to say that the integrity

of the pipe would be severely endangered if this problem were not resolved?

A It could be in danger, yes.

Q Yes.

DR. HARDY: Incidentally, Mr. Scott, that was not an accepted fact at the time that the research program was developed. We didn't know and so it is a mistake to go into this with the concept that at the time this research project on the frost heaving was drawn up and funded, that we knew that there was -- that there would be terrific damage to the pipe if we didn't get a solution.

We didn't know what the effect would be. We knew that frost heaving was a possibility, and we wanted to find out actually what it meant in terms of the integrity of the system.

Q I take it therefore, Dr. Hardy and Dr. Slusarchuk, that what you're saying is that the consequences of failing to solve the frost heave problem, have become apparent as you have analyzed the problem?

A No, this is not so, sir. I have been working in frost action in soils for many years before this, and I recognized that one of the problems that had to be considered was the effect of frost heaving on the pipeline. There was no answers for it in the literature.

Q Can I interrupt you, Dr. Hardy, to ask if when you began doing that, were you aware of the consequences of failing to solve the

problem?

A No.

Q All right.

A We didn't know precisely what the effects of the frost heaving would be.

Q Yes.

A On a line of this kind.

Q I take it then that when the studies began into the frost heave question, a question you knew you would have to investigate, it became apparent that if the problem wasn't solved , there would be serious consequences?

A Well, this gets into the area of the results of the program and I will turn it back to Dr. Slusarchuk.

Q Well, is that fair, Dr. Slusarchuk?

WITNESS SLUSARCHUK:

A Could you state the question, sir, you are asking me?

Q I understand from Dr. Hardy that the consequences of failing to solve the frost heave problem were not fully understood when the examination of frost heave as a phenomena began? Do you agree with that?

A I really don't know how to answer that, sir. I think I stated just a little while ago that with frost heaving, if you didn't know how to handle it, you could in fact endanger the integrity of the pipe. That's certainly my view.

Q Well, let me put it this way. I take it it is only after your research has begun, your research toward a solution, that you have become aware of the serious consequences for the integrity of the pipe, of failing to find that solution?

A I think we have been able to quantify it more, sir. I'm not sure I agree that we are not aware that there was a potential for jeopardizing the integrity of the pipeline due to frost heaving, prior to this frost heaving program.

Q Well when then, just so I'll have it on the record, did your research program begin in earnest?

A We started putting together our proposal for the major frost heave study, some time, April, May, sometime in May of 1973, I believe, sir.

Q Yes.

A And I think people were thinking about this prior to that time, and I can only speak around that time, because that's when I joined the company.

Q Well --

WITNESS MORGENSTERN: I think I would like to add--

Q Dr. Morgenstern?

A Prior to the formal documentation of the proposal, the problem had been identified earlier and scenarios of differential heave creating rupture if not resolved, clearly were

identified very early on, once we had recognized the need to pursue this.

Q Well, perhaps I can ask this question. Apart altogether from the proposal for the program, when did work in earnest begin on models that would produce solutions, or that it was hoped would produce solutions?

WITNESS SLUSARCHUK:

A At that time sir, about June '73.

Q Yes. Well now, Dr. Slusarchuk, could you describe for me, the worst geotechnical conditions that one is likely to find on this pipeline route that, define them by identifying them first of all, what is the worst situation in terms of the frost heave problem that one is likely to find on this route?

A The worst situation would be where you have a soil that has the characteristics such that it would heave the most.

Q Well I take it then that you are saying that the susceptibility of the soil is going to make for the worst geotechnical situation, is that correct?

A You are asking what seems like a very simple question, sir, and I would really love to give you a simple answer, but there are a combination of things that have to be considered, and that is the temperature of the pipe, the frost heaving characteristics of the soil, the depths that

you bury the pipe, and so on, and all of these things you have to put into your analysis to see what is the maximum rate of heave or the total rate of heave of one section versus another; for example, if you wanted me to tell you which was the most -- the worst frost heaving situation.

Q I withdraw that question and see if I can ask you this. In this 200-mile route what in your experienced judgment is the location that is likely to produce the maximum frost heave problem?

A I'm not sure -- do you want me to pin-point some spot along the --

Q That would be helpful and perhaps then we can identify the characteristics of that spot.

A No, I haven't identified that location,sir.

THE COMMISSIONER: What about a stretch as opposed to a spot?

A Well, any soils that have fine-grained characteristics we are considering to be potentially frost-susceptible, and you have to know the temperature of the pipe there, how fast the frost bulb grows, frost heave characteristics, what depth you build your pipe, and when you know that you can predict the rate of heat; and it's not until I can put all those together that I can tell you whether location "A" or stretch "A" is more frost-susceptible or going to cause me more problem than stretch "B" or location "B".

MR. SCOTT

Q Well, do I understand then, Dr. Slusarchuk, that you're not able to tell us from your work that stretch "A" or stretch "B" is likely to be worse or easier or anything of that type?

A Well, what we have done, sir, is that we are working to performance criteria for heave and what we have done is developed an analytical method to predict the heave. We have also developed -- we've got samples from along the route and we've used our geothermal analysis to predict the position of the frost front. From -- I've forgotten the question; I got so worked up in my points.

Q Well, I understand, Dr. Slusarchuk, that you have been working at Calgary with the Calgary test-site, and the geothermal analysis which we'll come to in a few moments; but I take it that is it possible now for you to assist the Commission by saying at Mile 150 to 175 the problem is likely to be more severe than it is at Mile 250 or 275, or are you simply not able to give us any assistance on that subject at all?

A I'm able to tell you at any place along that line I can predict the heave and maintain it within our performance criteria.

Q Have you done that?

A For all along the route?

Q Yes.

A No sir, I haven't.

Q Have you done it in any substantial stretches along the route?

A What we have done, we have located our samples along the route in various unfrozen zones, according to terrain type, whether

it's deltaic sand or a till soil, or something like that, and we have -- we are trying in the first instance or we are doing in the first instance tying in frost heave characteristics with the terrain type, for example.

Q Yes, but just so I'll be clear, do I understand then that you can outline a combination of circumstances which are likely to produce the worst situation?

A I truly, sir, don't understand what you mean by "a worst situation".

Q Well, you can tell us that if you have this kind of soil and this kind of temperature, and this amount of water present, that you are going to have a certain result?

A Yes, if what you mean by your worst condition , your worst situation is that we might have to apply the largest surcharge and bury the pipe the deepest, then I think we can tell you, we can analyze that situation .

Q But I take it that you analyze that, if I can put it this way, by reference to the components and you've not charted it out on the route of the pipe.

A We have identified unfrozen zones along the pipeline route, and in the first instance we have identified terrain units along there, and we are getting samples from those terrain units and have got them and we've tested them, and that is one of our first measures for correlating our

information, or grouping our information. For example, what is a heaving characteristic of a till compared to that of a deltaic sand sediment, a finer sand sediment that we find along the route? We have not done a mile by mile design.

Q Yes. I take it that you haven't also done, to use a river term, a reach by reach design, or a segment by segment design.

A No sir, we have not gotten into final design at all.

Q So that when in -- I should read you first of all the response to the Assessment Group's question 20 at page 20-3 of the response volume. The last paragraph on that page --

A On what page, sir?

Q 20-3.

A Yes, I have that.

Q Yes, the last paragraph about the eighth line from the bottom, the authors say:

> "The amount of heave that the pipe can be anticipated under worst conditions, and if no preventive or remedial measures are taken, is about six feet or a little more within six to ten years."

Now I take it, stopping there, that you're not able to tell us now where those conditions are likely to be found on this 200-mile route between Willow Lake and the Alberta border?

A I can't tell you by

milepost as per a mile -- final mile by mile design, no sir.

Q No. Well now, just looking at that answer, it covers some other matters that I want to deal with, but before getting to it I take it therefore that you're unable to tell us now what percentage of the 200 miles falls within or near the worst conditions?

A Yes sir, that's right, I can't put a firm percentage on that.

Q Could you put even a rough percentage on it? If you can't, say so. I don't want to ask you to say something that you don't know.

A No sir, it depends on the depth of burial that you'd have.

Q Leave aside the preventive measures as defined in that sentence, the amount of heave that will occur at the worst conditions, you have told us that you're unable, because it hasn't been worked out, to tell us any location or series of locations where those worst conditions may occur. What I'm not asking and perhaps the answer is obvious, are you able to tell us what percentage of the route is likely to be at or near those worst conditions?

A No sir, I can't give you a figure on that.

Q Well now, you say that at those worst conditions the heave, if no preventive measures are to be taken, is about six feet or a little

more within six or ten years -- six to ten years.

A Yes sir.

Q Now would I be correct in saying that the bulk of that heave probably occurs within the first four to five years?

A Yes sir.

Q But in other words there is a decline as time goes by in the rate or I'm not sure I've got the right language, but in the rate at which the pipe heaves.

A Yes sir, that's correct.

Q And that, I take it, is shown graphically on a chart conveniently on the last page of the Northern Engineering Services, "Results from Frost Effects" study with which you're familiar.

A Yes sir, I have that.

Q And that shows, does it not, that in four to six years you have come very close to six feet of heave?

A Yes sir.

Q Yes. Now, you have told us that in the event of one's failure to solve the problems of frost heave, that one would be concerned with a possible rupture of the pipe.

A Yes sir.

Q Do I also understand that short of the rupture of the pipe, there is a bending limit of the pipe which becomes, in engineering terms, unacceptable?

A You have to ask that to the stress analysis people sir.

Q I don't know who they are.

A They're the next panel.

Q Oh. I see. Well, were you given any guide-lines on that subject at all?

A Yes sir, we have been given performance criteria.

Q Well, in the addendum to the canned evidence of this panel at page 6 --

A Yes sir.

Q -- the panel says, and I forget who actually read this paragraph, do you have that in front of you, Dr. Slusarchuk?

A Yes sir.

Q The panel says, beginning at line 5:

"As an example in general the amount of differential heave over pipeline lengths of 100 to 150 feet should not exceed about 2 1/2 to 4 feet."

A Yes sir.

Q Now I don't know who answered that question. Was it you, Dr. Clark?

WITNESS CLARK: I read that into the evidence.

Q Would I be correct as reading that to say that at that point or within that

range, the acceptable limit of bending is reached?

WITNESS SLUSARCHUK: If you read your previous -- the previous sentence there, it says:

> "With respect to differential heave, our guide-lines,"

and by "guide-lines" that means our performance criteria guide-lines,

> "is that the pipe should not heave differentially along its length such that the serviceable radius of curvature is exceeded."

And it is that radius of curvature that we are talking about at that bend.

Q Yes, that sentence is reduced to language that is more meaningful to me by the sentence I read, and really what I'm trying to establish, if it is so, is that the limit of acceptability.

A That is the limit of acceptability from a stress point of view, but that is not the limit where you're going to start to buckle the pipe. People on other panels can explain that more to you, but the serviceability radius of curvature has a safety factor built into it.

Q Well, what I'm really asking, I suppose I can take the answer that is in the canned evidence and do what I want with it, but is it possible to reduce the margin that exists between 2 1/2 and 4 feet more closely?

Is it possible to be more precise about that figure? Either Dr. Clark, or you may know.

WITNESS CLARK: It would be more precise with an actual radius of curvature.

Q What you're telling me is you can't translate it into language I can understand more precisely?

A Well we did try to make it simple so it could be understood, and the two and a half to four feet, I believe it says in lengths of 100 to 150 feet. You see it two and a half feet over 150 feet would be below our radius of curvature.

Q I think I understand then. The two and a half feet relates to the hundreds, and the four relates to the 150?

A That's correct, yes.

Q Yes. And that would be -- anything exceeding that would be generally speaking unacceptable?

A Those are the bounds that have been, that we have been told we should keep the differential movement, not the total movement, but the differential movement within those bounds.

As to the serviceability of the pipe beyond those bounds, that would have to be spoken to by the stress analysis people.

Q Well now, is anybody on the panel able to describe where unacceptable differential heave, including up to rupture of the pipe could occur, assuming that there are no preventive or remedial measures?

WITNESS SLUSARCHUK: Excuse me, sir, I missed the first part of your question.

Q Are you able to describe

the conditions in which, assuming no remedial techniques, unacceptable differential heave and going as far as rupture, could possibly occur?

A Well, we would try to estimate the total heave along the route or along any section of the route, and the maximum differential heave that could happen over that length would be the total heave, assuming that one point was not heaving and the other point was heaving.

In fact, of course, they are going to be heaving, like both points would be heaving, and the total heave would not translate directly into differential heave.

Q Well, is it possible to give us a condition, an outline of the conditions or an example of that unacceptable differential heave? Dr. Clark may have something for you there.

WITNESS HARDY: I think Mr. Scott you should realize that the guidelines that Dr. Slusarchuk has referred to, he has pointed out a very important distinction, that in the initial circumstance you're talking about a stress level in the pipe, and he has said that guideline is not a stress level that will produce buckling of the wall of the pipe.

MR. SCOTT:

Q I think what I am really asking Dr. Slusarchuk for is the soil conditions.

A I know, but you see, you're asking what are the conditions that will result in rupture of the pipe. The system would be out of

operation before there was any rupture of the pipe, by buckling of the wall, and if the stress condition is eliminated, you get a permanent deformation in the pipe, and this may -- it won't put them out of operation, but can be objectionable.

Q Well, that's why I didn't restrict my question to rupture. I said, is it possible to describe the conditions when unacceptable differential heave, including rupture if you want to take the worst case, could possibly occur.

WITNESS SLUSARCHUK:

A We would relate that to the total heave, sir. We would look at the situations where we thought that we were going to have a lot of total heave, and if in our judgment we thought that you could get differential heave of two and a half to four feet over a length of a hundred to a hundred and fifty feet, then you could identify that, but if you were predicting a heave such as six feet such as you were referring to before, then it would be possible to, in fact -- it may be possible to get differential heaves of greater than two and a half to four feet.

Our plan, of course, is not to allow the pipe to heave that much.

Q Well, can you describe a geological condition that would lead to that?

A Well we've identified a couple of areas, there's sort of unfrozen area where you just have heave along the pipe and you might have a different frost heaving rate at one position versus

a heaving rate at another position. That could lead to differential heave.

You could also get differential heave say coming in and out of permafrost, for example. In a discontinuous zone, you've got an island of permafrost, that you're coming through and the area adjacent to that is an unfrozen area, where you have a frost susceptible soil and that starts to heave, and we brought up that point, sir, on page 6 there.

Q Well, do I understand the position to be this then, that you're not able to describe any concrete situation in which an unacceptable level of differential heave will occur?

MR. GENEST: You mean without remedial measures?

MR. SCOTT:

Q Without remedial measures?

A Yes, there's cases where without remedial measures you could get differential heave. I've already said, sir, that --

Q I think I am asking you to give me a case.

A Well I have given you two of them, sir. I've given you --

Q Would you mind repeating them, they weren't clear?

A The one is where you go from say permafrost to non-permafrost situation, and that -- we brought this point up on page 6, and the other is just when you're going along ordinary ground,

that's unfrozen but frost susceptible, and it's heaving at one rate here and another rate here.

Q I take it that you're not in the same way able to map, in any sense at this stage, where those conditions are more or less likely to occur?

A We have not -- what I was saying previous, sir, and it was because you asked me, was have we designed this more or less on a mile by mile basis, and said what's the heaving rate here and what is it there and what is it there, and we have not done that. But we can go along the route and identify areas that are unfrozen, areas that have fine grained soil and frost heaving characteristics. We can measure those and we have, and then we can determine the rate of heave along those stretches.

Q Yes, but you're -- I take it you stick with your previous answer that you're not able to pinpoint any area where either the worst conditions obtain or pinpoint any area or reach where the -- an unacceptable level of differential heave is likely to occur?

A Well if you're saying without remedial measures --

Q Without remedial measures.

A -- well then yes, I think I could.

Q Well all right, where are those worse conditions in this 200 mile segment?

A The worst conditions would

be where you have a soil that is heaving very quickly at, for example, say along the areas that might be designated DL or RKM and they are unfrozen, along the terrain types.

Q Well, what I am really getting at with respect to these two problems, and my friend is looking at his watch, is is it possible to show us on a map where the critical areas, assuming there were no remedial measures would be?

If I can give you a parallel, the rivermen, I gather, can tell us that this crossing is likely to be more critical in terms of problems than that? I wonder if it's possible, if it's not, tell us. Is it possible for you to tell us in this 200 mile segment, where the critical areas are from the point of view of worst conditions and from the point of view of worst differential heave, assuming in both cases, no remedial measures?

A We haven't gone through that exercise yet, sir.

Q All right.

THE COMMISSIONER: Excuse me, do we have coffee? I think we will adjourn then.

(PROCEEDINGS ADJOURNED)

(PROCEEDINGS RESUMED PURSUANT TO ADJOURNMENT)

MR. SCOTT: Q Dr. Slusarchuk, the questions I've asked you all related to situations in the absence of remedial measures, and just to review and to lay the groundwork for some particular questions I want to ask you, I take it from your response to the Assessment Group's concern at page 170, there are basically four remedial measures that you contemplate in the face of frost heave. The first is deep burial, the second is the surcharge or the berm, the third is the replacement of frost-susceptible soil with non-frost-susceptible soil; and the fourth relating particularly to -- relating exclusively, I think, to cases where there is dual piping, is an alternating of the flow through the two pipes. Are those the four remedies that have been devised?

WITNESS SLUSARCHUK: Those are the four major remedies, yes sir.

Q Now, would I be correct in saying that apart from the work at the test sites, including Calgary and the other test sites and the models to which you have referred, there is no precedent for the utilization of these remedies in a case of a chilled pipeline traversing the kind of area that is found in this last 200 miles.

A I'm not aware of any.

Q Yes. Well now, Dr. Clark, in connection with this you gave evidence on the question of drainage problems, and as I understand it, there are

two potential drainage problems, the first is the problem of surface drainage and the second is the problem of sub-surface drainage through what we counsel called the Carson Templeton Wall, which is the wall formed by the ice bulb. Have I characterized the two drainage problems?

WITNESS CLARK:

A Yes sir.

Q And I take it with respect to surface drainage, the -- generally speaking the solution proposed is a series of appropriately placed berm breaks.

A Are you referring to the areas where we have surcharged for frost heave, is that correct?

Q Yes.

A Yes, that's correct.

Q I take it where you have no surcharge, there will be no drainage problem at the surface in your judgment?

A No, that's correct. It's the spoil mound only.

Q Yes. Now with respect to sub-surface drainage, I understand that the solution proposed is the insertion of a pipe through the Templeton Wall, beginning outside the frost-heave area and ending up on the other side of the pipe outside the frost-heave area.

A That would only be applied where there was a significant flow which

essentially means an aquafer, the gravel bearing quite a bit of water.

Q Yes, but in those cases where there is what you characterize as a serious sub-surface drainage, am I correct that that is the principle solution on which you rely?

A That's correct, yes.

Q And would I be correct in saying to you that with respect to the sub-surface drainage solution there is no precedent outside of the laboratories and the test-sites for the usage of that device?

A I'm not aware of whether that's been used for sub-surface drainage.

Q Yes, and I take it that the only precedent for the berm break might exist in a southern Canadian community, or a southern Canadian pipeline where there is no permafrost problem.

A My understanding is that berm breaks were used, for example, on the Pointed Mountain line. Spoil mound breaks and similar methods to what we have described.

Q I see. Apart from the Pointed Mounted line, are you aware of any precedent for that solution?

A I believe it's my understanding is that it's a solution on virtually all pipelines, that they use these techniques.

Q What I was really asking

is in an area of discontinuous permafrost, are you aware of any cases where this solution has been used to respond to surface drainage problems over a frost bulb?

A Not over a frost bulb, but the -- several of the drainage measures have been used in one form or another on, for instance, roads and highways and forestry roads.

Q Now, Dr. Slusarchuk, have you formed any view as to how important it is to quantify the conditions along the 200-mile route that contribute to frost-heaving in order to estimate the amounts and rates of heave from place to place?

WITNESS SLUSARCHUK: Yes sir, I have.

Q And do I understand that your quantification technique is the geothermal analysis? And the terrain analysis maps.

A Plus the results of our frost heave tests that we've done on samples along the route.

Q Are you talking about frost heave tests that you've done apart from the test-sites?

A Yes sir.

Q Yes. When you say you've done frost heave tests apart from the test-sites, have you actually buried pipe in locations along the route?

A By frost heave tests, sir,

I'm referring to the laboratory tests that we are doing on our 4-inch diameter undisturbed samples that we've obtained from along the route.

Q Oh, I see. What you're telling me then is that your laboratory experiments have utilized soils that are found along the route.

A Yes sir.

Q You're not telling me that you've actually gone out without a permit on the route and buried a piece of pipe.

A No, sir, I wouldn't do that.

Q Too bad, that might be one of the ways to find out some of these things, but I take it then that your ability to quantify the conditions in order to estimate amounts and rate of heave, are based on the terrain analysis maps, the geothermal analysis, your laboratory models, and I think to be fair, your drill holes where they exist.

A Yes sir.

Q Well now, on the basis of that material, to what extent and in what detail have you been able to quantify those conditions to date? As to rate and amount of heave along the route.

A We have sampled, we have obtained frost heave samples from along the route at different locations, and obtained average frost heave characteristics for those soils, and we then look at the line temperature profile, for example, to

find what the temperature of the pipe would be at any location, and see what sort of rates of frost penetration we would get and then translate that into predicted heaves.

Q But I take it that at this stage you really have been confronted with taking only random samples along the route.

A Absolutely.

Q Yes, but there has as yet been no attempt to quantify the nature of the route itself as to amount and rate of heave.

A Other than through our terrain typing.

Q Yes, other than through your terrain types and your maps.

A Yes sir.

Q Well now, I take it that it is obvious that in order to do that a substantial amount of drilling will have to be done.

A We will have to do some more drilling, yes sir.

Q Are you in a position to estimate the extent of the drilling that will be required, let us say, on the Fort Simpson route?

WITNESS SLUSARCHUK:

A For frost heaving?

Q Yes.

A Are you talking now about final design, sir?

Q As you move toward final design, what is the rate of drilling that you will -- that you judge to be required before this quantification can be done?

A We haven't established that, sir.

Q I see. And I take it that when you come to establish that, one of the things you will know when you have established it on an area or reach basis, is the -- and assuming deep burial to be one of the solutions, the depth at which the pipe should be buried from place to place?

Well let me put it this way --

A You lost me part way through that, sir.

Q The purpose of this quantification, as you move towards final design, one of the purposes of it, is to tell you, assuming deep burial to be the solution adopted --

A Yes, sir.

Q -- the depth at which in any

given location --

A Yes sir.

Q -- you must bury?

A Yes sir.

Q And I take it you're a geo-technician, but you're not remote from economic questions, that the deeper you bury it, the more expensive it's likely to be?

A That's right. To a -- it depends how deep you're talking about. If you're talking about the depth of the ditcher, it's not very much more expensive, to go to that level.

Q Well now, as you move to that stage, is it important to know vertically and laterally the heterogeneity of the soil through which you are going to be passing over short distances in order to predict heave, differential heave?

A Yes sir, it will be a factor that we take into account.

Q Yes, well I would like to show you a sketch that we prepared which to say the least is not to scale, but -- and it's a sketch of a speckled bog, and I take it that you're familiar with that phenomena?

A Yes sir.

THE COMMISSIONER: It sounds like a rock group. It wasn't very funny. Heterogeneity is the other side of the coin to homogeneity, is it?

A Yes sir.

Q Are we using those words in

the right way, or am I?

A Well that's the way I understand it, sir.

MR. SCOTT: I should point out, Mr. Commissioner, that I had to experiment in the pronunciation of that.

Q Now, just as a point of reference, this is -- as a point of reference, a speckled bog is found on the Fort Simpson new alignment sheets 1M 02001019. Well now, Dr. Slusarchuk, have you done examinations of speckled bogs?

A We have considered them, sir, yes.

Q Yes. Well now, I take it that one of the characteristics of a speckled bog is that it is overlain usually with peat?

A Yes sir.

Q Yes. Well let us assume that to be the case there, and that let us assume that below the peat is silt till.

A Okay.

Q And I take it that that would be a reasonably typical analysis of a speckled bog?

A We found that in several places.

Q Yes. And because it's a bog, the water is -- or the water table is pretty well at ground level?

A Yes, sir.

Q And do you see the water

table there?

A Yes I do.

MR. GENEST: Could you show it to me, Mr. Scott?

MR. SCOTT:

Q Am I right, Dr. Slusarchuk, that appears to be peat indicating below that line into the depth, and this appears to be silt indicated below as it is shown and that would be a typical example of a configuration in a speckled bog, would it?

A I'm not sure how typical it is, but you can -- I imagine you could find it, all right.

Q You wouldn't be surprised to see that?

A No, I don't think so.

Q And the ground table in this example is at the top of the peat?

A Yes sir.

Q And I take it that that would be --

MR. GENEST: Did you mean the water table or the ground table?

MR. SCOTT: I'm sorry, I meant the water table.

Q And that that would not be an untypical situation?

A No, that is correct, sir.

Q And the dotted line that is

shown on both sides of the diagram is the line of permafrost?

A Yes, sir.

Q Distinguishing frozen from unfrozen?

A The other way around, sir.

Q I'm sorry, I had my fingers in the wrong place. Unfrozen on the bog side and frozen outside?

A Yes, sir.

I see a lot of red marks along there sir, I can't see them from here.

Q That's your pipe and we will be coming to that in a minute.

A Okay.

Q I want to ask you about the qualities of those two kinds of soil from the point of view of frost susceptibility. What do you say about silt till?

A Silty till would have a low shut-off pressure.

Q Would you characterize -- I suppose that teaches me for asking an open-ended question, but would you characterize a silty till as one that is or is not frost susceptible?

A Our position, sir, is you can't classify a soil as frost susceptible or non-frost susceptible, unless you talk about the pressures. This was part of the thrust of my show that I put on the other day, or whatever you want to call it.

Q Let's deal with those pressures. Where are the frost susceptible soils in that diagram,if any?

A The silty till would be more frost susceptible than the peat.

Q Well now, it's hard to see the red lines -- it's hard to see the red line, but stand up and come over if you can't, the top red line is designed to signify the bottom of the pipe. The dotted red lines that appear below it are the bottom of the frost bulb as it develops at one year, at two year and at ten years, and recognizing that that is not to scale, would that be a reasonable configuration?

A I don't think the position of the frost bulbs are very good.

Q Well then, where would you put them?

A Well I think it would penetrate down a little bit faster in the earlier years.

Q All right. Well then do I understand then that you think a frost bulb would proportionately move to 20 feet more quickly than is shown in this particular sketch?

A Yes, sir. The position of the first year to the second year, the first year would be closer to the second year than is shown there.

Q All right. Now, Dr. Slusarchuk, would you agree with me that that diagram with water at the surface, represents one of the

worst cases?

A Excuse me sir, could you say that again?

Q Would you agree with me that that diagram with water at the surface, represents one of the worst cases?

A It represents the worst case from the water point of view, yes.

Q Could you describe for us, how if at all, differential heave would occur in that diagramatic example?

A Should I go up there?

Q Yes, if it's easier for you.

A Well, you will not be heaving in this area.

Q You're indicating the peat area.

A Indicating the peat, yes.

Q And why is that?

A Because it doesn't have -- it has a very low shut-off pressure, a little bit of overburden pressure will stop that from heaving.

Q Yes?

A It won't be heaving over here, and again I'm indicating the peat. It will tend to heave in that zone there.

Q Well all right, could I stop you there and ask you a question? I take it the frost bulb will form more or less uniformly across that diagram.

A No, I don't think that's true.

Q All right, what do you think?

A I think the frost will penetrate faster here than it will on the peat.

Q You're indicating that the frost bulb will grow faster in the silt till than in the peat.

A Yes sir.

Q Yes. Now when you're

saying the frost heave is more likely to occur in the silt till than in the peat, I take it what you're saying is that lensing is more likely to occur at the frontier of the bulb in till than in peat.

A Yes sir.

Q Is differential heave going to occur at that point, at any point of frozen-unfrozen contact?

A Yes sir, right in through here.

Q Well now, I take it that that is a case at which some remedial measures will have to be taken.

A We'd have to analyze it first, sir, but it certainly is an area of potential.

Q Well, what is the remedial measure that you would contemplate as being a typical response to that problem?

A We could bury it a little deeper, or we could put a surcharge on it, sir.

Q Yes. Well now, Dr. Slusarchuk, this is a sketch, obviously, drawn by very amateur hands. Don't you agree with me that in order to determine what is going to happen in that piece of ground, you have to have a very clear understanding of what's under the surface in some substantial detail?

A If you were interested in accurately predicting the heave along there then you

would, yes.

Q And aren't you interested in doing that?

A To a certain degree, sir, but we plan to monitor the performance of our pipeline and from that point of view we would actually have a measure of what heave was going on.

Q Well, you have said that you're going to monitor the performance of your pipeline, do I understand, however, that you propose to build a pipeline in which the problems associated with frost heave will not occur, that that is your intention? Or are you going to build a pipeline in which frost heave will occur and it will be remedied subsequently?

A We would initially build a pipeline and apply our preventative measures at the time that we were constructing the pipeline. We'd monitor, and if at some time in the future we were seeing heave, different than what we thought we were going to get, then we would have to remedy that at a future date, of course.

Q Well, I take it that there is a difference of technique involved, that is it the position of Northern Engineering that they propose to take all precautions to ensure during construction, to ensure that frost heave will not occur?

A We're not trying to

ensure that frost heave isn't going to occur, sir. We're trying to ensure that frost heave is not going to occur to such an extent as to exceed the serviceability limit of the pipe.

Q Yes, so am I correct in saying that the position is that you are going to design a response to frost heave that will first of all ensure the integrity of the pipe?

A Yes, sir, that's what we're --

Q Yes, and that even in those circumstances, and with that kind of design, frost heave may occur.

A Frost heave will occur, yes.

Q And that the response to -- and that you anticipate it occurring.

A We anticipate frost heaving to occur.

Q So that your design after construction is based on an anticipation that frost heave will occur in the next five or six years, from location to location.

A After the pipe goes into operation and we have put on preventative measures, we are still going to get frost heave. Is that what you were asking?

Q Well, it seems to me that it's a question of design technique. I may be wrong

because I'm a neophyte, bit it seems to me that it's a question of design technique, you are either going to design the pipe and the remedial measures to rule out for all practical purposes the occurrence of frost heave by placing your over-burden during construction. That's one possibility, isn't it?

A We don't have to eliminate frost heave, sir. We only have to keep frost heave down to -- to use our example -- 2 1/2 to 4 feet within a length of 100 to 150 feet.

Q Yes, that's --

THE COMMISSIONER: That's the differential, is it, that you're talking about?

MR. SCOTT: Yes.

A That's the differential heave.

Q You don't have to eliminate frost heave for the purposes of ensuring the integrity of your pipe.

A That's correct.

Q All right, well I'm not concerned about frost heave in that context. I'm sure that Northern Engineering will devise ways of looking after the integrity of its pipe; but I take it that what you are saying to me is that your design of deep burial or berms will be such a design that it will ensure the integrity of the pipe first of all.

A Yes sir.

Q But it will anticipate

that following construction there will be from place to place frost heave.

A There will be frost heave. Now, this doesn't -- I'm not sure whether you're asking whether that means we'll go to do remedial measures from place to place, we're anticipating that.

Q Well, that's what I'm getting at, and that your remedy for that frost heave is to observe and come in and apply extra overburden as required.

A We are now talking about a substantial amount of frost heave.

Q Yes.

A Not just frost heave, and then these will be very localized cases.

Q But I take it, I take it, Dr. Slusarchuk, that it is possible as a design matter -- I'm not saying it's the preferred way -- but it's possible as a design matter to construct your pipe, bury it at a given depth, apply a calculated overburden, which will affectively prevent frost heave above the berm.

A We seem to get in the same position, you keep saying there's no frost heave and I keep telling you that we're going to have frost heave.

Q Well, I meant heave of the pipe, I'm sorry. I meant heave of the pipe.

A Well, we're going to get

heave of the pipe, and that's part of our design. We're not stopping or eliminating all frost heave, we're just keeping it within limits.

Q Yes, and the remedy that is contemplated in your design is inspection and the placement of overburden at various periods of time as required.

A Yes sir. If we didn't put enough on to start with, and we monitored and we found that it was starting to heave too fast, then we would go in and do what you're suggesting.

Q Yes, but do I understand you to say that you don't intend to put on the optimum amount that will prevent the pipe heaving up?

A No sir.

Q Are you intending to maximize the berm so that at the conclusion of construction you will be able to say, "This pipe should not move."

A You've got two questions in thereand you keep saying the pipe isn't going to move. We can except the pipe moving, and maybe you could break up your questions one at a time so I can answer them one at a time.

Q Well, I take it that one of the remedies proposed to prevent the pipe moving is deep burial.

MR. GENEST: Excuse me, Mr. Commissioner, but my friend keeps repeating "to prevent

the pipe from moving" and the witness keeps saying "the pipe is going to move". The real question is a differential move or a move beyond acceptable limits.

MR. SCOTT: All right, let me rephrase it.

Q I take it that your remedy to prevent differ-- unacceptable differential movement is one deep burial, or two, the addition of a berm.

A That's correct, sir.

Q Yes, and I take it that you are not designing the placement of the pipe on the basis that at the conclusion of construction you will be able to say, "This pipe will not move beyond acceptable limits".

A We're going to attempt to do that but in case the ground has been different in some cases than we anticipated, we are going to monitor and that will tell us whether or not we need to go in again. But we are planning to go through, construct and put a proper depth to the pipe and a proper berm so that we're not throwing the problem over to the maintenance people, to say, "You keep adding more berm on there to keep the pipe down" we're going to run through our calculations and our analysis, and if say we're going to need a certain amount of overburden and a certain depth of pipe in order to keep the differential heave at a certain level, that's what we're going to do.

Q All right, so you should be able to say at the conclusion of your work, assuming the construction people do what you tell them, that "We do not anticipate the necessity of adding more overburden."

A We can't say we don't anticipate it, because if we didn't anticipate it why would we go to all the trouble of monitoring it?

Q Well, I think that's a fairly crucial point. At what rate do you anticipate? Obviously, you can -- it's quite conceivable that you can design a line in which you bury at a certain level, and overburden at a certain level, and in which you anticipate, they may be economic, but major remedial steps.

I take it from what you say that what you're doing, is you're saying under ordinary circumstances, we're going to build this so that it would not -- and bury it and overburden it where required, so that it will not move within --without the acceptable limits, and that we're going to monitor just to be sure that we were right?

A That's correct, and to allow us to take remedial measures if we were wrong.

Q Yes, and if you are totally right, the number of remedial measures will be very, very small?

A That is correct.

Q Well now, don't you agree with me that in approaching that speckled bog complex, you really -- in order to determine the depth of burial, or the overburden required, you are going to have to do an indepth analysis of that phenomena as it appears?

A As we go across speckled bogs, we are going to analyze it and do it in depth, that's correct.

Q Well, are you going to do

test excavations at sites like that?

A We are going to have the ditch.

Q Well I know you are going to have the ditch, but -- and we'll come to whether when you have the ditch it's too late, but are you going to do test excavations before you have the ditch?

A Well, we will put down bore holes along there and get some samples.

Q You intend to do bore holes?

A Yes sir.

Q Do you intend to part from bore holes to do a test excavation at any site?

A Not at the moment sir, we don't have that plan.

Q Allright. Well now, in a situation like that, how closely spaced would you anticipate the bore holes will be?

A Well, this is sort of a matter that we were going to be determining in final design, exactly how close we're going to be requiring bore holes. We haven't determined that at this time, sir.

Q Well now --

WITNESS MORGENSTERN: May I add a point here? We would also make use of geophysical techniques to profile,so that you are not fully relied on just bore holes.

MR. SCOTT:

Q I'm not sure that I understand what you mean by geophysical techniques?

A Seismic and electrical resistivity profiling and other sensing devices that will pick up the silt till contour without actually having to put a hole down every ten feet.

Q Well now, on page 15 of the canned evidence for this panel, this answer is provided: "The site specific drilling will be completed in sufficient time to allow detailed specifications to be prepared for all facilities. It is not expected that a great deal of additional drilling would be required for the pipeline route itself, as the terrain typing and the verification test drilling would prove adequate for most of the final mile by mile design".

Now, do I understand that this kind of example is a case in which Northern Engineering will want to do fairly extensive test drilling before final design?

WITNESS CLARK:

A We are continuing now with test drilling to broaden the data base that we have for different soil types, but in a situation like this, we would attempt to optimize the test drilling by the use of a geophysical survey.

Q What concerns me about the problem is the assertion by -- in the recorded answers, which I read to say that the drilling program is substantially finished, it is not expected that a great

deal of additional drilling will be required.

A No sir, we are talking about two things here. One is the site specific drilling, and the site specific drilling would relate to such things as slopes, areas of complex terrain, relative to frost heave such as you have illustrated --

Q Yes.

A -- specific sites for compressor stations and so on.

Q Well, would the answer in the canned evidence then have been more accurate if it had indicated your intention to do, in particular sites, reasonably extensive drilling before final design?

A The intensive drilling would be in localized areas.

Q But I take, and this would be one of them?

A This could be one of them. We have recently done some drilling at similar sites to this already.

Q Well I put it to you, Dr. Clark, and it seems to me that this may be what you intend, that there will be a substantial number of sites along -- I'm talking about the 200 mile section now, in which you will require very substantial drilling in particular sites?

A That's correct, yes.

Q Yes. And it would be correct, therefore, to say that when you come to difficult situations in the final design stage, there

will be an extensive drilling program to determine the nature, precisely what is underneath the ground over which you must cross?

A At specific sites, yes.

Q Now, you referred, or Dr. Morgenstern referred, to geophysical techniques that would be utilized. Was I correct? Did I -- has a geophysical survey on this 200 mile section been done?

A We have not as yet done our geophysical survey. It's in the planning stage, the early planning stage right now.

Q Wouldn't you have expected it to be done by this stage?

A No.

Q Are you behind on that?

A Not at all.

Q Well, when is it anticipated that that will be completed?

A That is part of the study now is to determine the optimum time to do it, relative to --

Q To do it.

A -- relative to the final design.

Q What type of geophysical survey are you presently contemplating?

A That will be determined by our geophysicist who is at work now on a report to present our recommendations as to the type.

Q But I take it that there

is no intention with respect to specific and difficult areas, to do an excavation before final design?

A We don't plan to open up any large test pits.

Q Do you contemplate the possibility that you may have to, in order to get adequate knowledge?

A Well in fact, we have opened up test pits where they have been appropriate. We have opened up test pits very recently to get certain types of samples, but in this particular situation that you have described, we would not be relying upon a test pit in the middle of that speckled bog.

Q Well now, let's look at that example just again in terms of how the pipe will work. I take it that you have the pipe, and Dr. Slusarchuk, it's your judgment that the bulb will develop all along the pipe, but at varying degrees, depending upon whether it's in peat or in silt?

WITNESS SLUSARCHUK:

A Yes, sir.

Q So that the bulb in the silt area will get bigger faster than the bulb in the peat area?

A Yes, that would be my estimate, sir.

Q So what we have in this bog is not a consistent bulb as you might have in one soil type, but a bulb that shows a configuration?

A Yes, sir.

Q And isn't it correct to see the pipe when the bulb has formed, as I think some member of the panel referred to it, as a new object, maybe 30 feet in diameter at its maximum growth. Wouldn't that be correct?

A Yes, it would be 30 feet in diameter.

Q So it's wrong after the frost bulb has been created to think simply of the pipe. We must think of a frozen object, let us say 30 feet in diameter, in the middle of unfrozen soils?

A Yes, sir.

Q And the exterior of the frozen object is earth, and it's not unlike concrete, is it?

A No.

Q It's not concrete.

A It's different that concrete, sir.

Q Yes, but I put it to you that you can visualize this by imagining a 30 foot diameter concrete bulb with a steel liner in the centre of it?

A I don't believe that would be a correct analogy.

Q Well, how would you analogize it?

A I wouldn't try to put an analogy to it, sir. It's just frozen soil around a piece of pipe.

Q Well let me put a -- my analogies are notorious, so I will withdraw that one, but I take it that when that situation has developed, one cannot think of the movement of the pipe except in terms of the movement of the frozen area around it?

A Yes, sir.

Q Now that frozen area around the pipe is variable in quality and quantity?

A You mean because it's going from the peat to the till, is that what you are referring to, sir?

Q Well first of all, in terms of quantity it's variable because you've told us it's bigger in the till area than in the peat area?

A Yes.

Q And it is -- I.take it that it is also variable in terms of quality in the sense that it may be more closely or more densely packed in one section of the till than in the other? As a result of the configuration of the earth?

A Well that's possible, certainly.

Q Well now, I put it to you that the steel has one strength, which is reasonably consistent, isn't it?

A Yes, sir.

Q But I put it to you that the so-called concrete around the pipe, because of its variations in quantity and quality, has a variety of different strengths?

A Within the frozen mass?

Q Within the frozen mass?

A It could very well have that, sir.

Q Yes. The frozen peat will be either stronger or weaker than the frozen silt?

A Yes.

Q And have you considered how, in terms of differential heave, how these forces in what I call the concrete, are going to work?

MR. GENEST: Why doesn't my friend call it the frozen ground, because nobody has agreed that it is concrete.

MR. SCOTT: All right, very well, Mr. Genest.

Q Have you considered how those forces are going to work with the pipe?

A We've considered it, yes, sir.

Q Well, what is your conclusion?

A By and large, take for example, the centre of the silt till mound there, just where you have got your five foot. You would start to freeze your frost bulb around there, and by and large, sir, my conclusion would be that the frozen soil around the pipe would act more or less like a solid body, a rigid body.

Q Isn't it possible that as the pipe is warped under differential, and that will occur, won't it?

A Yes.

Q But as the pipe is warped under differential heave, the warping or some of it will concentrate on the weaker parts of the soil?

A Could you just go over that again, sir?

Q Let me put an analogy to you. If I take -- maybe another example, take a pencil and let us assume that the inside lead in the pencil is the pipe, and the outside wood is the frost bulb, a convenient, and in this case and unlike that case, uniform sized bulb. Now the pencil isn't long enough, but I can bend that and it will bend generally evenly along the pencil. You're familiar with that, aren't you?

A Yes sir.

Q Yes. If there is an imperfection in the wood, the pressures will concentrate at that imperfection, won't they?

A In that case they would, yes.

Q If I cut a line in the pencil, the pressures would -- the warping pressures would concentrate at a point where I've cut.

A The pressures would or

the bend would? It would certainly bend more there.

Q Well, it will bend there to the point of breaking, won't it?

A On your pencil it might.

Q Well, what I'm suggesting to you is that in a situation like this, where you have different kinds of soil, different dimensions of the bulb, presumably a variety of factors, it is an extremely difficult and complex matter to measure the performance of the pipe.

A Well, we're talking about the example, at the centre there, and we're considering the frost bulb, now to be a rigid body. I'm not quite sure where the complication arises.

Q Well, what I'm really saying by this example is that isn't it possible that as the pipe is warped, as it will be under differential heave, the warp -- not all the warping but much of the warping will concentrate on the weaker parts of the soil jacket.

A I don't think that's right, sir.

Q You don't think that's so?

A If you're telling me that most of the bending -- well --

Q Isn't that so?

A -- are you saying most of the bending there would then take place in the

peat and not in the silt?

Q No, I don't know enough to make a choice. I'm simply saying that if there are weaknesses in the soil cover, that the pressures of the warping may concentrate at those weaker points.

A Yeah, maybe I'd like to retract my answer in not agreeing with you on that. I think that the tendency would be to have some of the bending occurring in the softer material there, at the interface between the softer and the stronger material.

THE COMMISSIONER: Which is the softer and which is the stronger?

A The peat is the softer, sir.

MR. SCOTT: Q Well now, I take it that that kind of phenomena is likely to occur at any location where there is a difference in qualities, the performance qualities of the soil, the frozen soil around the pipe.

A It's possible that there are differences going to occur; whether they are going to rupture the pipe or not is another question.

Q But if those differences occur, isn't it so that the warping will concentrate at the weaker areas?

A Could I have one second, please?

Q Yes, by all means.

A Could I pass that question over to Dr. Morgenstern?

Q By all means. He's been grabbing for the microphone for about 15 minutes now.

WITNESS MORGENSTERN: If I could try and translate the concern. A non-uniform heave of the pipe will generate a non-uniform stress in the frozen soil. Was that the concern?

Q I think that's the concern. Thank you. That's all right.

A Could you then go on?

Q That the warp will concentrate in the place of weakness.

A The frozen soil is significantly stronger than the unfrozen soil below, so that if you're concerned about excessive deformation developing in this frozen encasement around the pipe, it would be limited by the yielding below in the unfrozen soil. If the local stresses become large, they could only be limited by the capacity of the unfrozen soil to transmit them. Therefore this would not contribute to aggravating the bending of the pipe.

Q So that the analogy of the pencil that I posed, are you saying that the analogy of the pencil, imperfect as it may be, doesn't apply; the pencil would have to be surrounded with unfrozen soil to make it --

A To interact. The total interaction is not simply one of frozen soil and pipe.

It's unfrozen soil, frozen soil, and pipe.

Q Well, I take it first of all that the phenomena that I've attempted to describe is likely to occur, the concentration of the pressures.

A Non-uniform distribution of stress leading to intensification locally is certainly a possibility.

Q Yes, and do you say that no problem is associated with that because of the presence of surrounding soils?

A Yes.

Q Well now, Dr. Slusarchuk, did you have any criteria from which you can describe the degree of frost susceptibility of various soils along the route?

WITNESS SLUSARCHUK: Our interest in frost heaving is to predict the rate of frost heave, and our criteria -- the way we describe frost-susceptibility would be to put our rate of heave on, for example when you're talking about quantifying it, the rate of heave that we would get over some period of time, that is the function of overburden pressure.

Q Well, in your volume results from frost effects study, at page 56, paragraph 3.6.6.2, entitled:

"Frost susceptibility classification of Calgary silt,"

there is implied, at least, as we read it, the existence

as we read it, of criteria against which the classification will be made.

MR. GENEST: Would my friend read that portion of the report from which he draws that implication?

MR. SCOTT: Yes.

"Tests were carried out,"

and I'm reading,

"Tests were carried out to classify the frost susceptibility of Calgary silt according to the T.R.R.L. frost susceptibility classification. This classification was then compared with the results of the frost effects testing program. Following the procedures set out by Sutherland & Gaskin in 1973, two tests were carried out on Calgary silt samples, one remoulded and one undisturbed."

I'm sorry, Dr. Slusarchuk, have you not got the page?

A No, I've got it, I'm waiting for the question. I have it sir, yes.

Q Well, do you have a criteria from which you can describe the degree of frost susceptibility of soil deposits along the route?

A This -- there have been traditional frost susceptibility classifications and we use one and we refer to one there.

Q That's the T.R.R. L.?

A Yes sir.

Q Yes.

A And there's a -- in the next paragraph we also refer to one from the cold regions Research & Engineering Laboratories, the two that are fairly standard use. These have been developed for guidance with regard to developing -- with regard to designing frost heaving for roadways and air strips, in other words a classification -- a frost susceptibility classification developed for low overburden pressures.

Q Well I --

A Can I finish, please?

Q Yes.

A We were aware of these tests, of course,and in order to have a tie-in with the body of data of frost susceptibility in the literature we ran two samples of our Calgary silt from our field test facility in order to ensure ourselves and to demonstrate to people with knowledge in these standard frost susceptibility tests that that soil was indeed frost susceptible. We then carried it on farther and used the overburden pressure as another parameter and what we have shown, for example, the standard classifications would say that the Calgary silt soil was highly frost susceptible, we know that if we just put a couple of thousand points per square foot on that same soil we won't get any ice lensing at all, and therefore it has to be classified as non-frost-susceptible. So if you don't bring in the overburden pressure concept into classification, from our point of view it is not applicable. This was simply a tie-in from our

work to previous work that was done. Classifications do not apply to our particular conditions.

Q Well, I take it the criteria is in fact the T.R.R.L. frost susceptibility classification. Is that correct?

A That was the one that we referred to here and in the next paragraph we also refer to the C.R.R.E.L. the CRREL the Cold Regions, there are two separate tests.

Q Well, those I understand that both of those are traditional tests.

A Yes sir.

Q And is it correct that both of them -- what is the basis of both of them?

A They freeze a small sample of soil, four inches in diameter, six inches high, and they put a certain temperature at the surface and a certain temperature at the base, and they measure the heave over a period of 250 hours, and the amount of that heave they have a classification, they go over and see if it heaves so many centimeters, it's highly frost-susceptible or non-frost susceptible.

The main point here is that they do it at practically no overburden pressure, where the rates of heave are extremely high.

Q Yes. Well now, within the context of those two criteria established by those classifications, what are traditionally considered to be the frost-susceptible soils?

A I think most people would consider silty soils in the area highly frost-susceptible.

Q Yes. Well, can you give me sort of a ranking of a variety of soil types that are commonly found in the Mackenzie Valley?

A In an unfrozen area we have --

Q I take it that the most susceptible is silt, is it, generally speaking?

A That's according to those traditional ones, yes.

Q All right,

Q Now, where do we go after silt?
A Well you can go both ways. You go over to a finer grained soil such as clay, and they're generally rated as not so highly frost susceptible. We could go the other way to the sands, the grain size of the silts being in between the sands and the clay and then on into gravels, that would be not frost susceptible.
Q Well for a layman like me, and utilizing the traditional classification technique, --
A M'hmm.
Q -- I take it that the concept at issue here is the spacing between the grains, and the grain size?
A Grain size, yes.
Q So that you have sand at one end and clay at the other?
A Yes.
Q Not at the ultimate ends, but --
A Right. I understand your analogy, sir.
Q Yes, and sand is granular, it has larger grains and more spaces between it, as opposed to clay which has tinier grains and therefore smaller spaces between them, and silt is a nice compromise between the two?
A Yes, sir.

Q And silt, because of -- and in that range,sand, silt and clay, according to the traditional tests, silt is regarded as being the most frost susceptible?

A Yes, sir.

Q Yes. Well now, is it not possible that other soils like clay at one end, which are normally regarded as less frost susceptible,are in fact frost susceptible over the long term?

A Yes, sir.

Q Now --

A We have said that, sir, in our application.

Q I'm not quarrelling with it. I'm just asking if that's your view.

a Okay. That's true, yes.

Q And I take it it therefore follows that significant heaving over the long term can occur in clay soils?

A It's possible.

Q Well now, is the rate of freezing of a frost susceptible soil an important consideration from the point of view of the formation of ice lenses?

A In some instances it is, yes.

The rate of freezing around our pipeline is pretty constant, and I presume you are relating your question to our pipeline.

Q Well let's take the rate

of freezing first and then we will get to your pipeline.

I take it as a general principle, the rate of freezing may have impact on the extent to which ice lenses are formed?

A Yes sir.

Q Yes. And I -- does it also follow from that, leave aside your particular pipeline for the moment, does it also follow from that that different rates of freezing in somebody else's pipeline, could affect differential heave?

A The different rates of freezing can affect differential rates of heave, is that the question?

Q Could different rates of freezing enhance differential heave?

A In some cases it could possibly enhance it, and in other cases it would probably reduce it.

Q But I take it that what it will do is it will affect differential heave one way or the other?

A It could, sir, yes.

Q Well now, is it possible that varying gas temperatures in the pipeline, assume they vary, that varying gas temperatures could affect the rate of freezing at the bulb?

A Are you varying it from at one point in the pipeline from year to year, or are you varying it along the pipeline?

Q I'm varying it along the pipeline, for the moment.

A And the question again then, was?

Q And the question is, could a variety of temperatures within the pipeline affect the rate of freezing?

A Yes, sir, that -- the temperature of the pipe affects the rate of freezing.

Q Yes, and therefore I take it that a variety of temperatures, if such existed, could affect the question of differential heave?

A Well, the temperature along the pipeline, this is what you're asking me to consider, does not change hardly at all over a short length.

Q Well I understand that that is the company's answer to the problem, but I just want to get the problem first, and I take it that if you assume the situation in which the gas temperature varies at various sections of the line, that may affect the rate of freezing?

A If the temperature varies, it affects the rate of freezing, yes.

Q And the rate of freezing affects, or enhances the differential heave?

A It affects -- it can --

Q It alters --

A Yes.

Q -- the rate or the extent

of differential heave?

A Yes, it can do that.

Q Could you provide for us, just as a sample, to be commented on later, a range of typical cut-off pressures, related to the, in terms of the depth of overburden?

A I believe --

Q Let's take silt of some kind, first.

A The silts that we have been measuring, their cut-off pressure has been somewhere in the order of a couple of thousand pounds per square feet.

Q Well is that approximately 2,000 pounds per square feet? Let's take that. How many feet of overburden is that?

A It would depend on where the water table is, sir, but it could vary from say 20 feet to 40 feet.

Q Well now, what about other typical soils on the route apart from silt?

A The sands and finer sands, the silty sands, would have a cut-off pressure, we have measured a couple somewheres in the neighbourhood of about 500 pounds per square foot.

Q Equal to how many feet of overburden?

A Five to ten feet, sir.

Q What about clays?

A Clays. We have found that

their cut-off pressures are a little bit higher, up around 3,000 pounds per square foot.

Q And how many feet of overburden would that represent, typically?

A Thirty to fifty feet, for example.

THE COMMISSIONER: Excuse me. Thirty to fifty feet of overburden?

A Yes sir. Yes sir, 3,000 pounds per square foot is -- that's the sort of stress level you would find, thirty to fifty feet beneath the ground.

MR. GENEST: That is for shut-off pressure?

MR. SCOTT: It is an equivalent table, isn't it? You're giving us the pounds per square foot, and then telling us what that equals roughly in terms of overburden?

A Yes, sir.

THE COMMISSIONER: Well, so I don't lose the thread of this, is there any relationship between that figure required and the distance between the top of the pipe and the surface of the earth or the surface of the berm? The upper surface?

A You could -- the weight of the pipe is not really contributing very much to the situation, sir. Is that your question? Are you asking if the weight of the pipe --

Q No.

A What -- could you give us the question again, sir?

Q All right. Thirty to fifty feet of overburden is needed in a particular kind of soil that Mr. Scott described, to put an end to frost heave.

A Yes sir. By the overburden, like what he's asked me to translate is what the cut-off pressure was, and I told him what that was, and I have translated that --

Q Now cutoff pressure means what is needed to put it into frost heave.

A Yes, sir.

Q Or to lensing.

A To the lensing.

Q To the lensing, all right.

A And --

Q To put and end to the continuing formation of the ice bulb, the frost bulb?

A No sir, the frost bulb is still going to keep going, except it's not going to suck in water from the unfrozen ground --

Q Yes, all right.

A -- and freeze lenses. And if you want the stress level in the soil equivalent to 3,000 pounds per square foot, it would be something similar to what you'd find between 30 and 50 feet beneath the ground surface.

Now, we just -- just a hundred pounds per square foot of soil times 30 feet equals

3,000 pounds per square foot. That's the only calculation I'm doing here.

THE COMMISSIONER: Okay.

MR. SCOTT: Can I -- Mr. Commissioner, it might be that if I put the point I was making a little more directly, it would be understood.

Q I take it, Dr. Slusarchuk, that it's your analysis that the -- that when the cut-off pressure is achieved, lensing under the bulb effectively terminates?

A Yes, sir.

Q Yes. And therefore, the thing that makes the bulb heave, the presence of the lens , ceases to develop?

A Yes, sir.

Q Yes. And that the cut-off pressure can be measured in terms of earth above the point?

A It can be measured in terms of pounds per square foot, which then can be translated into depths beneath the ground surface, yes.

Q And what you are telling me, as I understand it, is that in silt, you've got silt and you want to prevent the lensing, you've got to put, let us say roughly, either 2,000 pounds of pressure on that surface, or you have to have 20 to 40 feet of silt on top of the lensing area?

A On top of the lensing area, that's correct, yes.

Q All right.

A That doesn't mean we are building a surcharge of 50 to 100 feet.

Q Oh no, no.

a Okay.

MR.GENEST: Does my -- would my friend object, I just -- I may be getting the wrong impression. Where is it measured from? Is it from the bottom of the ice lens, or from the bottom of the frost bulb?

MR. SCOTT: It's measured from the --

MR. GENEST: Or the top of the frost bulb, that's where I am confused.

MR. SCOTT:

Q Isn't the point this, that your studies have shown that frost lensing, in silt for example, will not occur generally speaking, more than 20 to 40 feet down in the silt?

A Yes, sir.

Q Becase then you have 20 to 40 feet of silt and lensing seems to stop?

A Yes, sir.

Q With that pressure. Now, the top of it, to clear it for Mr. Genest, can be the surface of the ground, or it can be an over-burden?

A Yes, sir.

Q The --

MR. GENEST: I was getting at

the bottom, Mr. Scott. I just don't want there to be any confusion between the level of the pipe and the lower level of the frost bulb.

MR. SCOTT: I'm not talking about the pipe at all now. I'm just talking generally.

Q I take it another way of expressing that 20 to 40 feet, is to measure it in terms of weight?

A Well, --

Q 2,000 pounds.

A Weight is, you know, stress sir. Pounds per square foot.

Q Yes.

A All right.

Q All right. Well now, that has led you to conclude that if you can calculate the overburden that you can then apply a pressure or a depth that will terminate lensing?

A Yes, sir.

Q And that's the whole key to the depth of burial principle, or the berm principle?

A It's not the whole key, sir.

Q Well a substantial key?

A Yes, but it's important how fast, how the overburden reduces the rate of heave while it's getting down to the cut-off pressure.

Q Well then, what --

A You see what we are worried about, we worried about the amount of heave that's going to happen to the pipe, and it's important to know how the heaving is occurring prior to coming to a stress level of the cut-off pressure.

Q But wouldn't you agree with me that that principle that the cut-off pressure can be obtained by weight or depth in any given soil, is one of the central principles upon which your solution to the frost-heaving problem depends?

A Yes sir.

Q Yes. Well now, I take it that that determination has been made at the Calgary test-site and in your analysis of the problem with the box models that you earlier described.

A And mainly from our frost-heave tests on our 4-inch diameter undisturbed samples, sir, that we do in the lab.

THE COMMISSIONER: Well, I'm listening, anyway.

MR. SCOTT: Q Well, the problem that concerns me is that we heard Dr. McKay in the overview, and he's also written a paper on this subject with which I'm sure you're familiar, in which he described segregated ice -- I think it's at Richards Island or near Tuktoyaktuk or somewhere up there -- at a depth of 140 feet. How could that occur if this principle applies?

A Well, --

Q First of all, could I ask you, are you familiar with his paper?

A No, I'm not with that particular paper, no sir.

THE COMMISSIONER: Well, Dr. McKay was a witness here. There's no argument about his qualifications, I take it. Or is there?

A There's no question about Dr. McKay's qualifications with regard to ground ice; I'm not sure he's a frost heave expert.

MR. SCOTT: I don't put him forward on that basis. I put him forward first of all as an observer, and the reference to which I want to make -- I understand it's not really called a paper, it's called a memorandum of the geological survey of Canada, 71-21. Are you familiar with that?

A Not straight away, sir. I may have read it once, I don't recall it.

Q Well, in that he says -- and my friend will criticize me if I read the abstract, he's talking about observations made in the Tuktoyaktuk Peninsula, and the abstract says -- I should read it because I take it it makes sense:

"Icy sediments where present occur with relatively constant frequency to a depth of at least 140 feet."

A Ice what, sir?

Q

"Icy sediments where present occur with relatively constant frequency to a depth of at least 140 feet."

Now are you familiar with the existence, according to Dr. McKay, of that observable phenomena?

A I understand that there is ice to those depths, yes sir.

Q Well, how could that phenomena occur and be rationalized with your principle of cut-off pressures?

A I'm not --

WITNESS MORGENSTERN: Could I add a comment here? There are several processes that could account for it. One, of course it could be part of the depositional history of the area that wasn't at that depth when the ground ice was formed. But many of us feel, and I think, in fact I can cite Dr. McKay here, as a person who has produced field data in support of the origin of massive ground ice beds at substantial depths that are the result of expulsion processes during freezing. When the pressure on the freezing ground exceeds the cut-off pressure, the water instead of being sucked towards the freezing front is in fact expelled away from it, and it will then find a location in which to form certain sill like or tabular forms of ground ice. So that the further range of increasing overburden pressure also gives us mechanisms to provide segregated ground ice. I suggest that's one of the processes that we think

accounts for segregated ice at depth.

Q I take it, Dr. Morgenstern, that without explanation the observations of Dr. McKay require rationalization with the cut-off pressure principle.

A Yes.

Q Without explanation the two can't stand together in any rational system, without an explanation such as you've given.

A Yes.

Q Now, are there any other possible explanations, apart from the one you've given?

A My observation of the geological history, of course, accounts for or at least embraces a complexity of geological environments, erosion and depositional features leading to a complex stratigraphy. It really in itself takes into account a lot of conditions.

Q Well, what I'm concerned about is apart from a hypothesis, of what assurance is there that Dr. McKay's observations do not reveal an inconsistency in the cut-off pressure theory?

A The cut-off pressure theory has been explored over the range of heat fluxes, soil conditions, that we're concerned with in the pipeline. The observations of Dr. McKay lend themselves to several interpretations. I don't see an inconsistency, we've obviously addressed this point, and while we may not -- there isn't a general agreement today on

the origin of these massive ground ice beds which we find around Tuktoyaktuk. There is some fascination but I think it's explained in terms of expulsion process, that's my view. Others may hold a different view.

Q But there are other theories for their existence.

A there are many, and it takes a great deal of local geological data to begin to decipher them

Q What I'm concerned about is what assurance can we have that they are not a phenomena that is inconsistent with the cut-off pressure theory over let us say, a 150-year winter?

A Our assurance.

Q Well, on such matters, great communications industries have been built; but I --

A I think to pursue it further. One would have to become more site-specific and discuss stratigraphy and look at the peculiarities of the ice features. We certainly addressed the question that segregated ice is found at greater depths than one would infer from just putting a shut-off pressure on at the outset of a geological process, in all of the cases we've looked at we think can be accounted for by expulsion process, we think it's a very important feature in the development of segregated ground ice and by complexities of ground surfaces and freezing programs.

Q So according to that, is it so that if the bulb were 100 feet over many years, no doubt, that ice lensing would occur at the bottom of the bulb?

A If the bulb were 100 feet deep in the sense of the pressure exceeds the cut-off pressure?

Q Yes.

A Then it would begin to push water away from it, and there wouldn't be lensing beside the bulb but you'd be getting some accumulation -- well, the snow, of course, elsewhere.

Q there would be no lensing, you say --

A Beneath the bulb.

Q Yes.

A It would be expelling water from it.

Q Isn't it true that with respect to this theory and this pipeline, the analysis has all been done with -- by tests at the test-sites and in the laboratories?

WITNESS SLUSARCHUK: This is not to just the overall cut-off pressure concept and the effect of overburden on the rate of heave. The Polar Region Research Engineering Laboratories, they carried out pretty extensive studies on that in Alaska several years ago where they actually surcharged the ground surface at different overburden pressures

and measured the rates of heave there, and this is, I think, back in 1964.

Q Yes, but isn't it so that all the testing that has been done has been done over a 1, or 2, or 3-year period?

A Our testing has been, but there are other people's data available like Aikin, the fellow that wrote that up, I think that was in '66, Bennel & Capler did a similar thing previous to that, and the phenomenon of overburden pressure reducing the rate of heave has been known since as far back as about 1930.

Q What was the period of their tests?

A How do you mean "the period"?

Q The period of time over which they made observations?

A I can't give that to you right now, sir.

Q I put it to you that the thing about what's been observed at Tuktoyaktuk is that it's had many, many years potentially, it's had many, many years to develop.

A Hundreds of years.

Q Yes, and what is being described for us here is what will occur in a relatively short span, four to six years, or ten years. What assurance have we that -- apart from what Dr.

Morgenstern has said about other explanations, what assurance have we that over a long period of time it may not be shown that the cut-off pressure over a constant winter doesn't act the way you think it will?

A Well, we've done numerous tests on different types of soils in the field, and from the Calgary test-site in our 4-inch undisturbed samples to get their frost-heaving characteristics. We have done a number of tests on our model box with regard to overburden pressure, and with no overburden pressure. We have had four different test-sites, test sections out at our test-site and we have not noticed any inconsistency in any of the work that we've done there that can't be explained by our basic philosophies or our design concepts. We think that our concepts are rational, and that we have shown them to in fact be applicable, and other than running something for six years, I'm not sure how you can answer your question.

Q Well now earlier when you were at the chart, you were referring to monitoring procedures that would be carried out following the construction. Could you outline for us, the monitoring procedures or the control procedures that in your judgment are necessary? To deal with potential heaving?

A We haven't decided on a final method at the moment, but there are several methods available to us. One method would be a method similar to what we are using at the field test site. Have riser rods come from the pipe up above the ground surface, and we would simply take elevations on those riser rods, and it would give us an indication of what the pipe is doing.

Q Yes. That's sort of a surveying technique, is it?

A Yes, sir.

Q And what intervals would you anticipate it might be wise to go into the pipe and do this?

A Well to start, you would want to do it every, I know, every two or three months, something like that, but all your action or most of your action is taking place in the first few years, so after three or four years, you would be pretty sure of what was happening, and as time went along, you wouldn't do it as often, quite clearly.

Q Have you given any consideration to using a pig that goes down the pipe?

A Yes sir.

Q Are you going to do that, or do you know?

A We haven't made a final decision on that, sir, but it is one of the things that we are considering.

Q Are there other techniques of monitoring that are underconsideration?

A We are tentatively looking at some geophysical methods.

Q What do you mean by geophysical methods? I'm not clear what that means.

A Similar to what Dr. Morgenstern described previously, with running a piece of equipment along the line and perhaps --

Q Is this on top of the line?

A On top of the ground, sir.

Q On top of the ground, or --

A You would send out signals of one sort or another that would be perhaps based on, like for an example, based on the difference in magnetism or the properties of the steel versus the properties of the soil.

Q Is there any time table during which we may expect to know how the monitoring is going to take place? Perhaps that is for Dr. Clark, I don't know.

WITNESS CLARK:

A I would suggest that that

decision would be made about the time that we would produce our design manual. The geophysical application is being explored now, but I'm sure that some of your advisors could tell you how rapidly the technology is developing in that area.

It is under consideration now as a technique along with the others that Dr. Slusarchuk has mentioned.

Q The point that I'm concerned about is that obviously some of the observational techniques require travel at regular intervals, of persons along the line and others don't. I wonder when we may expect to have some assurance whether the first alternative is a possibility or whether it's not?

A That's about the time that we would have our design manuals, part of .final design --

Q I see.

A -- that we would make that/ decision

Q And I take it, Dr. Slusarchuk, when in this monitoring process you find what I will call unanticipated heave , the remedy is going to be overburden, is it?

WITNESS SLUSARCHUK:

A That's one of our remedies, yes.

Q Are you at that stage going to regard the other three potential remedies, that is a deeper cut, changing the soil or twinning, as possible remedies?

A We wouldn't go in and bury the pipe deeper, and what was your other --

Q Well, they're your remedies, not mine. The other is twinning, and alternating the gas. You're obviously not going to do that, I take it, as part of the monitoring process?

A Not as part of the monitoring process --

Q Well as part of the repair process?

A If, for example, we were monitoring the frost heave at a river crossing, and we saw that the heave was such that it was starting to become unacceptable, then you can't surcharge quite clearly. The -- you could think about putting down steam points, for example. We are just talking about places where there are no twins, now.

Q Yes.

A No twin lines.
You could thaw out some of the soil underneath it, or you might be forced to build another line.

Q So, would it be correct to say that when the monitoring process is underway, the remedies that in practical terms are going to be available to you at that stage, are perhaps at water crossings, twinning if necessary in the first place, in the second place increasing the overburden -- are you going to consider utilizing changing the -- removing the frost susceptible soil?

A No, sir, I don't believe we

would.

Q So would it be correct to say that when you come to monitoring and repair, it's then going to be too late to bury deeper as a remedy or to change the soil as a remedy?

WITNESS CLARK:

A No, the soil could be changed by rapidly freezing. You could go in and artificially freeze the soil to increase the effective overburden pressure at the frost bulb. In other words, instead of three years or five years, the freezing could take place over a matter of days.

Q In that monitoring process, is it conceivable that the pipe could ever get out of the ground?

WITNESS SLUSARCHUK:

A No, that is our second guideline, sir, that the total heave of the pipe is limited to movement equivalent to coming up to about one foot beneath the ground surface.

Q Well what I'm getting at is that 10 or 5 years from now, am I going to read somewhere in the paper that a plane has gone in because a hunk of the pipe appeared above the ground?

MR. GENEST: You'll hear about it at this hearing.

MR. SCOTT:

Q Is that a risk?

WITNESS CLARK:

A We don't see that that is a risk, no.

Q Well now, one other substantial subject, you presently propose to refrigerate the pipe right down to the Alberta border. First of all, how did you decide on that limit? In terms of map making it's convenient, but how did you decide to stop there, rather than further north?

A I think that earlier on in the cross-examination by Mr. Templeton, we rationalized that it was very clear that we carry it down to the discontinuous zone frozen.

Q So there's no doubt about that, and that would end at about Willowlake, would it?

A About the Willowlake River, where we get into the discontinuous, the frozen part, the part that is mostly frozen, beyond there there is an area where it is not entirely critical as to where you stop it. We figure we have picked the optimum point to stop it, where the frost heave that would occur within that area could be tolerated, and beyond that area, the settlement that would accompany the degradation of the permafrost could be tolerated.

Q It's obvious, is it not, Dr. Clark, that the further south you get from Willowlake, the greater the proportion of unfrozen soil?

A That's right.

Q Yes, and I take it that

the proportion of ice rich soil in those frozen areas, also lessens markedly?

A It lessens, yes.

Q What I am concerned about is that it seems to me that when you are south of Willowlake, you are confronted with a relatively modest proportion of frozen soils, and a relatively modest proportion within that, of ice rich soils?

A Yes, there's some ice rich soils there, yes.

Q And that what you are doing, therefore, is you are running the risks of frost heave to protect a relatively modest proportion of permafrost?

A No, we don't see the frost heave as a risk. We see it as a controllable phenomena that would be to our advantage to deal with frost heave, as opposed to thaw settlement in that case.

Q Well let me put this situation to you, that when you get south of Willowlake, there are areas of permafrost.

A Yes.

Q They decrease in volume as you get down to the border? In proportion to unfrozen soil?

A Yes.

Q And where they exist, I suggest to you that the temperatures of the permafrost are very close to 32 degrees as we used to call it?

A Yes.

Q You might have 31.8, 31.9, marginally at the freezing point?
A Yes.
Q Yes. Well now, the first thing you are going to do when you build this pipeline, is you are going to cut down all the trees and take up most of the vegetation?
A We wouldn't be taking up the vegetation.
Q Well, you will be cutting down the trees along the route?
A The trees will be cleared.
Q And then you're going to dig the trench and put in the pipeline and bury it?
A That's correct.
Q Yes. And you're not going to begin to chill it until two and a half or three years from the commencement of the operation has passed?
A That varies with the construction.
Q Well, you're not going to -- it's going to be at least two years, isn't it?
A Yes, that's correct.
Q All right. Well now, I put it to you, if the temperature is so marginally close to the freezing line, that before you begin to chill, that permafrost is going to move from 31.8 to 32.5.
A Some of it will, yes.
Q And that in the very

process of building your line, you will be forced to -- at least on the route,to destroy the frozen soil?

A It wouldn't be destroyed, it would be thawed.

Q It will be thawed,so that the proportion of permafrost that exists there now, will be substantially reduced after construction, but before freezing?

A I don't think it would be substantially. Our thermal analysis that we have done doesn't support that conclusion.

Q Well let me put this proposition to you. I take it that your only interest in freezing the pipe is because of the environmental concern?

A That's predominantly the interest, yes.

Q Is there any other interest?

A We feel that it's a more secure pipeline.

Q Cold than hot?

A In permafrost.

Q Oh, in terms of integrity?

A Yes.

Q Yes. If it could be demonstrated to you that the construction procedures would markedly reduce on the right-of-way the amount of permafrost, would you be prepared to recommend to your client that the chilling point should be moved further north?

A I would see as our responsibility to, in final design, to optimize this pipeline, and if there was a distinct advantage to moving the chilling point farther north, we would not be fulfilling our professional responsibilities if we didn't recommend that.

However, our assessment is at this time, is that there is no distinct advantage.

Q Has your assessment, your geothermal analysis taken account of the effect of cutting trees on the line?

A It is certainly my understanding that it has.

Q Has it taken account of ditching and the year and a half of construction?

A Yes.

Q Is the geothermal analysis and the prediction of temperatures a prediction after two years of cutting trees and digging soil?

A Yes.

Q Just so I'll be perfectly clear, do I understand that the only issue in chilling as far as you are concerned is - - has to do with the integrity of the pipe and the environmental impact.

A That's correct.

Q And I take it that you have made a recommendation to your client on the basis of the material that you've shown us, as to where the chilling should stop.

A Yes, that's correct.

Q And are you aware that your client has had any reservations about acting on your recommendation?

A I'm not aware of any. I think I mentioned when talking with Mr. Templeton that there is this grey area, it could be one way or the other. It's hard to be precise to a point, and we did want to keep some options open in fixing that last point of chilling.

Q I take it that's particularly true, isn't it, because of the Fort Simpson route change where there are a limited number of bore holes, and your knowledge of the temperatures in the routes is much less.

A We have less knowledge of

the actual temperature from measurements which we have made, however we have made an assessment of the quantities of frozen soil in that route.

Q But just so we'll put this issue aside, do I understand you to say that there is no economic consideration whatever in chilling or non-chilling?

A Oh, I think there have been substantial economic considerations on chilling.

Q Acting on your recommendation ?

A The economic analysis would be made by the people who are doing the flow studies.

Q But that's not Northern Engineering.

A No.

Q Well then, what I'm getting at is there another factor here which has played in your recommendation as to the chilling cut-off point, namely an economic factor?

A The economic factor would relate to the protection of the environment and the ensuring the security of the line. In other words, we feel that the costs associated with inhibiting frost heave burying deeper are not very great in proportion to the line when it's put in the perspective of how much frost heaving soil we have. It may be an economic --

Q What are the costs that play against that, if you decided for example north of Fort Simpson to stop chilling, what would be the costs that --

A Well, the costs that I would consider would be those associated with the security of the line, the integrity of the line, and the environment, the physical environment, if we were thawing it, thawing the frozen portions.

Q Well, what sort of costs would be involved to the company in that circumstance?

A Oh, the costs associated with maintaining drainage and erosion control, controlling settlement of the line in certain instances.

Q Well, I take it, however, there has never been any suggestion on which you've acted that there is an economic factor in chilling apart from the maintenance of the line.

A I understand that the economic factor associated with chilling is related to the type of chilling, but my understanding is that there is no economic -- no major economic advantage in throughput, for instance.

MR. SCOTT: Mr. Commissioner, we have a long way to go. I'd be prepared to go an hour or two this afternoon, if -- in order to deal with these matters.

THE COMMISSIONER: I think

that would be a good idea. Any objection, Mr. Genest?

MR. GENEST: None at all, sir.

THE COMMISSIONER: And I think your panel would prefer to continue.

MR. GENEST: I think they would.

THE COMMISSIONER: Well, let's adjourn until 2:30.

(PROCEEDINGS ADJOURNED TO 2:30 P.M.)

(PROCEEDINGS RESUMED PURSUANT TO ADJOURNMENT)

MR. SCOTT:

Q Dr. Clark, can you tell me when the decision was made to chill the gas to the Alberta border?

WITNESS CLARK:

A I can't recall that from memory. I believe the next panel could give you more precise information on that than I could.

Q Can you tell me generally?

A No, I would have to check that.

MR. GENEST: I will see if I can find that out right now.

Late '72, I am informed, Mr. Scott.

MR. SCOTT: Thank you very much.

Q Dr. Slusarchuk, in addition to the berm of overburden, you have listed three other methods of keeping the pipe down. You have told me that two of them only will be utilized in remedial work. Is Northern Engineering in any position to say whether in fact they are going to utilize the techniques, removal of frost susceptible soil or insulation of pipe? Are these presented as possibilities, or are they going to in fact be used from place to place?

WITNESS SLUSARCHUK:

A They can be used, sir.

Q Well I know they can be

used, but are they going to be used?

A We plan to use them, yes.

Q You plan to use them. Are you in a position to estimate for us over what proportion of the pipe they may be used, or how extensively?

A A very small proportion, sir.

Q I take it that the berm is going to be the substantial remedy, is that correct?

A That and the deep burial.

Q And deep burial.

A Yes, sir.

Q Yes. And can you tell us in what category of situation removal of frost susceptible soil is going to be the remedy of choice?

A When we bring the pipe out of the ground, for example, around compressor stations, we probably -- we plan to use gravel in those areas.

Q Yes. Any others?

A We don't have any others in mind, sir, that I'm aware of at the moment.

Q All right. In what circumstances are you going to use the insulation of pipe?

A At river crossings, basically.

Q Are you going to use --

A At small river ones, small river crossings.

Q Is that only under the river?

Or are you going to use it on ground aswell?

A Basically under the river, sir.

Q I take it it will be used under small rivers where there is a permafrost base?

A Generally -- yes, sir.

Q Yes. Now dealing with the insulation of the pipe, is it the intention or the is it possible to utilize -- and it's a depth of insulation that will totally prevent any freezing outside.

A We haven't investigated thickness or anything like that. I'm not sure whether theoretically there could be, but we're not proposing anything like that, sir.

Q I take it then.that you're proposing a kind of insulation in which freezing will be transmitted from the pipe beyond the insulation?

A Yes, sir.

Q And I take it that it therefore follows that over a period of time a frost bulb will develop, even around insulated pipes?

A Yes, sir.

Q But it will be a smaller frost bulb?

A It will be a smaller frost bulb, and the idea would be to use it where convection, or where you have your stream running in the gravel and the heat that would be brought to the frost bulb with the moving water would in fact

counteract the tendency for the bulb to move. That's the reason why we try to use it in those cases.

Q Well now I take it a smaller frost bulb, as a result of insulation, will mean the lenses are formed closer to the surface?

A Yes, sir.

Q And that therefore because of the smaller frost bulb, there will be a smaller overburden?

A Yes, sir.

Q Well doesn't that lead one to the conclusion that the capacity for lensing will not be cancelled out by an overburden?

A I was thinking, sir, of small streams where there was gravel to several feet underneath the river bed and you didn't want to freeze that off, or another -- or alternatively you didn't want to allow the frost bulb to get into the frost susceptible soil that might be at depths of 20 to 25 feet beneath the gravel. The first 10 to 20 or 25 feet would not be frost susceptible.

Q Do I understand then that the insulation will be used only in non-frost susceptible soils?

A The frost susceptible soil would be underneath the gravel. I don't -- we are not contemplating to insulate in soil that is actually frost susceptible itself.

Q So that remedy will not be used in cases where the pipe passes through frost

susceptible soils?

A But the frost bulb with time, sir, may advance into frost susceptible soil underneath the gravel.

Q Yes.

A Okay, and the reason you put the insulation on there is to reduce the heat flux of the pipe, have the frost bulb tend to be smaller, the effect of the convection would tend to keep the frost bulb even smaller, and the frost bulb would then not reach the frost susceptible soil underneath the gravel.

Q Thank you. Well now let's deal with the dual pipeline river crossings and I take it that the scheme here is that you're going to pipe the gas through one river crossing, chill, and then after an interval you're going to cut off that pipe and ship it through the other pipe.

A Yes sir.

Q Have you given any thought to the intervals that are going to be utilized? First of all, is this a serious remedy , a remedy seriously proposed?

A It's a real possibility, certainly .

Q But is there anything that suggests to you that it's going to work?

A Yes.

Q I take it that that's advanced as a serious solution for this problem.

A It's advanced, sir, as a method by which we can take advantage of the dual crossings with regard to frost heave at river crossings.

Q Yes, well have you any studies that indicate, for example, over what period of time after the gas is cut off in one pipe, warming is going to occur and the development of lensing terminate?

A We have done a couple of geothermal studies on that, sir.

Q Well, have you got them?

Or can you give us a reference to your studies with respect to this remedy?

A We do not have that in a report, no sir.

Q Isn't this entirely a theoretical proposition?

A It's not -- I wouldn't consider it theoretical. We've analyzed it from a geothermal point of view, and we know that because of the warm nature of the soil underneath the pipe that the frost bulb would tend to stop growing at an earlier stage because of the warmness underneath the river, and therefore in our opinion would reduce the total frost heave.

Q Well again, isn't the risk here that you will produce a smaller frost bulb?

A Yes, you produce a smaller frost bulb but I think we probably run the one for a few years, say for two or three years, and drive the frost bulb down quickly.

Q Well, how many years? What's the data on this remedy? Are you going to alternate it every two years, or five years, or three months?

A We haven't established that, sir, but we have established that conceptually it seems to be quite a reasonable thing to think about.

Q I don't want to be disrespectful of any of the very significant work that

you've done, but I sense that with respect to this remedy, that it seems to be something drawn on the back of a cigarette box as a concept. Has it been analyzed and proved out as a remedy?

A It's been analyzed to the extent that I've analyzed it, sir. We haven't carried out any field tests or anything like that on it.

Q Well, isn't there a risk that the smaller frost bulb is going to again mean a lower overburden and more lensing?

A There is a possibility but on the same token, while there was a shutdown you would have some thaw back and you'd have to re-freeze that to come back to where you were.

Q Are you going to use this remedy in frost-susceptible soils?

A No sir, we're only going to use it where dual crossings are already there and there's a potential use of a dual crossing.

Q So that when we come back to frost susceptible soils, we really have three remedies. Well, we have deep burial. I take it that's not a remedy, is it? You're either going to do it at the beginning or not at all.

A That's a design measure, sir.

Q Yes, so that with respect to frost-susceptible soils, the remedies are removal of that soil and adding to the berm.

A Those are also design measures.

Q We'll be coming to it later but I take it the cross-delta is in frost-susceptible soils.

A It is in soil that is classified as silty and some silty clay, which then makes it a potential for frost heaving.

Q There is no doubt, is there, about the fact that those soils are classified as frost-susceptible?

A Well, sir --

Q According to the traditional classification.

A -- according to them, they certainly would be.

Q All right. Was one of the purposes of the Calgary test-site to deal with the -- on a test basis -- with the differential heave problem?

A No sir, not directly to check out differential heave, and how it reacts with the -- inter-reacts with the pipe.

Q I take it that the answer to my question is "No, it isn't for that purpose," is illustrated by the fact that the lengths of pipe are only 40 feet long.

A Yes sir.

Q And I take it that at the

Calgary test-site, whatever else may be said about it, you basically are using soil of one classification type.

A There are different layers there down to about the 11-foot level you have a more silty soil, and as you go down beneath that a little bit deeper you start to become more fines in it, but generally you'd classify it as a silty soil.

Q And as a result, at Calgary, you don't have at the Calgary test-site the wide variety of soils adjacent one to the other as they will be found in the line itself.

A No sir.

Q And additionally, I take it that you're experience at the Calgary test site, has been limited basically to one year?

A Yes, sir.

Q And that what you've had to do at Calgary is take your findings with your 40 foot pipe in that kind of soil over one year, and extrapolate them, which I understand is the expression, to the life of the 25 year pipeline?

A We try to do more than that. We've tried to establish that we had a rational design methodology and to prove that out, and at the same time to use that hard data of one year's operation, and then of course we had to extrapolate beyond that.

Q Yes. Does a rational design methodology mean a concept?

A No sir, it could mean that, or it means that in part, but to me it means something that you've proposed and you've checked out, and you've noticed no inconsistencies in the various tests you've been running, and you're reasonably satisfied with the predictions that you can make.

Q Yes. Well, isn't it fair to say, that in order to move from your theory and the tests on the ground at Calgary, you have to over one year, you have to extrapolate a very substantial amount to get the conditions that are going to confront this pipeline in the field?

A We plan to operate the pipe in the field for 25 years or so --

Q We don't want you to do any experimenting there.

A -- we have only run the test sites for one year, so it's quite clear that we have to extrapolate that extra --

Q And that's a substantial extrapolation, isn't it?

A It's substantial in time or in percentage of years, say one over 25 or something like that, but --

Q And it's substantial in terms --

MR. GENEST: Let him finish his answer.

MR. SCOTT: I'm sorry. Is there anything else?

A It doesn't necessarily mean it's substantial with regard to the appropriateness of our design methodology.

Q Well, don't you think you are taking a fair calculated risk that the experiences of your laboratory will be borne out in the field over 25 or 30 years?

A There is a judgment that we have to apply to the numbers that we are getting and to the predictions. The -- we have used our controls -- our restrain section, for example, to simulate what was going to happen at -- as the frost bulb would penetrate deeper, which would be 5, 10, 15 or 20 years down the road, so even though there is

only a one year period there, of test results, there is tie-ins between what we are getting and what we foresee to happen in the future.

Q Well now, did I understand you to say in your evidence in chief, that the situation at the test site at Calgary represented in terms of sub-soil and ground water conditions, the worst possible situations that could be found in this route?

A Not on the route. I think we -- I'm not -- maybe we should have a look at exactly what you are referring to there.

Q But what do you say about the soil and water conditions that are found at the Calgary test site?

A We've said that they are traditionally recognized as frost susceptible soils and we have a water table that can produce -- supply the water that is required for frost heaving all at once, and in our view it represents a frost heaving condition that is representative of a worst case condition .

Q Yes. Well now, what about clay soils over long periods of time? That hasn't been tested at Calgary?

A No sir.

Q No. Well, is that not possibly a worst condition?

A It's possible that it could be similar to a worst condition or that over the lifetime of the pipe it could heave similar to

what this kind of soil could heave to.

Q What's the water table at Calgary?

A It's about six feet, sir. Six feet beneath the ground surface.

Q So that example I gave you on the diagram is much worse than anything you have at Calgary?

A It's not worse from the point of view of supplying water to the frost front beneath the bulb, sir.

Q It's worse in terms of water table, isn't it?

A But that's not the point, sir. The point is, is where the water is coming from that is going to grow the ice lenses to cause the heave of the frost bulb in the pipe, and as long as the water table is approximately equal to the base of the pipe, we are not restricting the availability of water for that soil to suck in all the water it wants.

The situation that makes it worse in your particular diagram, wherever it's gone to, is the fact that the water table is higher and it reduces the effective stress of the soil, and it has a tendency to reduce the overburden pressure and the stress on the frost front. That's the effect of the ground water table there being a worse case --

Q Yes.

A -- not of restricting the supply of water.

Q Yes. But I take it that with a water table at surface, you create a situation worse than existed at Calgary?

A We'd create a condition that frost heave would heave faster, yes.

Q Yes. And that's worse?

A Well, it could be worse. We were trying to determine, we were trying to examine our design methodology, or develop our design methodology to formulate our predictions and our procedures for that, and we could have made a situation worse by putting the pipe right at the ground surface, for example.

Q Dr. Slusarchuk, looking at the last diagram in your book, "Results from Frost Effect Study," the last page, --

A Yes, sir.

Q -- it's perfectly clear, isn't it, and perhaps you've said this, but the development of heave is much greater where the water table is at the surface than when the water table, for example in your diagram in one of the lines, is five feet down?

A It's worse because it reduces the effective stress. It's not worse from the fact that more water is available, that's the distinction I'm trying to make, sir.

Q All right. I understand why it's worse, I simply put it to you that that factor creates a situation that is worse than any at

the Calgary test site?

A It would create -- the pipe would heave faster under those conditions, yes sir.

Q And I take it a situation in which there is artesian water is worse than any that exists at the Calgary test site?

A Yes, if the flow was substantial, or in other words, that the excess pore pressure at the depths that we are talking about, due to the artesian pressures, would in fact reduce the effective stress of the frost front.

Q And artesian water in this context, as I understand it, means not water from a well, which is what I thought until a week ago, but rather water that is under some kind of pressure that will bring it above the surface of the ground?

A Yes, sir.

Q Yes, and that pressure can exist because it is collected and there is nowhere for it to go?

A Yes, something like that sir, yes.

Q And that would be a worse situation than existed at Calgary?

A Marginally.

Q Yes. Have you any idea how frequently artesian pressures -- artesian waters exist along this route?

A I understand that along

the portions of the east side of the Mackenzie River is a discharge area, and where water is coming up from below, up towards the surface, and that would be quite a number of miles. I'm not exactly sure what it would be.

Q Well, I take it what you're saying -- I'm sorry -- do you know anything else about artesian water anywhere else on the line, its location, the extent to which it may be present in the soils?

A Not myself, sir.

WITNESS CLARK: One of our colleagues is expert in this area that we have chosen by reason of phasing to bring him on in Phase 2. He works very closely with us in the frost heave program, so --

Q Is there a study or report, Dr. Clark, which will reveal that information?

A We have had a recent reconnaissance of icings that will ultimately end up in a report. I believe there are some other references, but not that we have produced, Mr. Scott.

Q Well, I take it what you're telling me is that there isn't a report now.

A No.

Q There may be in the future.

A Yes.

Q Dr. Slusarchuk, what is the explanation for the tilting of the pipe at the Calgary site which is shown, I think, on one of the graphs in your studies? The graph, for the purposes of the record, that is shown as figure 2.48 "Heave profiles along pipe section, October 1974."

Do you have that? I don't have a page number for it.

WITNESS SLUSARCHUK: Yes, I have it here, sir.

Q It's about the middle of the book, a third of the way through the book.

A 244?

Q 2.48, I'm sorry.

A Well, the reason for the tilting there, sir, is it was heaving faster at one end than at the other end. I might add further that with regard to the control sections, the end there that is not heaving quite as quickly as the other end, you have to bring your ducts into the ground and some of the weight from the ducts was also acting on that end of the -- of the buried pipeline, which would add a little bit of additional stress. The other thing is that theres a little bit of a change in the frost heaving characteristics along the -- of the soil underneath there, and it is creating that tilting.

Q Well, do I understand then that the explanation for the variation in heave that is shown in that chart is that it is one , that each of the pipes at one end were connected to some facility which may have had the effect of weighing them down at that end?

A On the control sections, sir, I am referring to specifically there in that --

Q Would that be near the zero end of the graph?

A Yes sir.

Q And is what you're telling us is that there's a pressure because there's a tap or an input or something?

A We tried to isolate the load from the ducts onto the soil, but in fact the pipe -- the duct there was on skids and we didn't realize it for a while, and then when we did realize it, we did in fact then jack it up so that the load was no longer on there.

Q Well, I put it to you that without, leaving aside that explanation for the moment, there is the most extraordinary variation in heave, bearing in mind that the pipe goes through, as you've said, relatively homogeneous soil, over nearly 40 feet.

A You're talking about the control sectionnow, sir? Of that line?

Q I'm talking about at least three of them. The control, the gravel, and the restrained.

A Yes, there is a tilt to them.

Q Apart from the tap being on the end, is there any other explanation for that, what appears to be a marked variation?

A Other than that there are different frost-heaving characteristics underneath the pipe, over that length of 40 feet.

Q And these different frost-heaving characteristics exist in a soil over 40 feet that is notably homogenous.

A It's not homogenous in that sense, there's a tilting to the soil layers in that area and at around -- depending on what section you're talking about, there is a little bit of a difference between the soil that is freezing at one end compared to the other. But it's not tremendously different.

Q But the soil is all within one soil classification.

A Yes sir, that's correct.

Q Yes, and it's not a difference in soil characteristics that could be detected by any of the devices you've described that you're going to utilize in the valley, is it?

A Well, we certainly could detect the difference in that soil from / our frost heave testsin the lab.

Q Yes, but when you come to lay the pipe you're not going to be able to tell whether the minor differences in soil classification that led to the tilting at Calgary exist from mile to mile up the valley.

A No sir, that's correct. I want to make a point here, though, sir, that though it's tilted it's remarkably straight, and our design criteria is the curvature of the pipe and if you look

at / these you would note that there was very little stress induced into the pipe, due to frost heaving.

Q Well, those pipes were only 40 feet long, weren't they?

A That's right, sir.

Q Is the expression, "the stress history of a soil" familiar to you?

A Yes sir.

Q Can you -- as Mr. Genest would say -- can you tell me what I mean by that?

A It's the cycle of loading or unloading that may have been put on the soil, either due to, for example/ the glaciers coming over and retreating, deposition, additional soil being deposited on it or going / through a freeze and thaw cycle.

Q Well, could you tell me if I'm correct when I suggest to you that the stress history of the soil is the extent to which the soil has experienced a load, experienced in the past a load higher than its present overburden?

A That could be one component of stress history, yes.

Q So in layman's terms, when you look to the stress history of the soil, you want to know to what extent there have been pressures on it before that are now not present?

A Yes sir, that would be --

Q And why is that significant?

A In most of our work, sir, we haven't considered it significant. It does have some implication if you're crossing at river crossings where the soil is not really dense and has a tendency to consolidate upon freezing.

Q Well now, do you consider that it's a significant factor, this stress history of any given piece of soil in approaching this problem?

A We haven't considered that to this point, sir.

Q Well, I want to read you one sentence from a paper by Dr. Morgenstern, I presume he's a doctor -- Arvidsson, called

"Water Flow Induced by Soil Freezing."

MR. GENEST: Just a moment, it's a paper by Dr. Morgenstern but it's by somebody else?

MR. SCOTT: No, it's by him and --

MR. GENEST: Somebody else?

MR. SCOTT: -- somebody else, I presume he's a doctor, as everybody but Mr. Williams seems to be.

A He is not.

Q He's not. W.D. Arvidsson at that time with R.M. Hardy & Associates, presented to the 27th Canadian Geotechnical Conference at Edmonton in November of 1974, and the abstract of it reads --

MR. GENEST: Whose abstract?

MR. SCOTT: The abstract which is attached to the paper which I presume is either prepared by or approved at least by the authors, I don't know how you abstract these things.

MR. GENEST: I'm just trying to distinguish it from yours.

MR. SCOTT: Perhaps I should read it all:

"A method of assessing the freezing behaviour of a soil is developed, This assessment is based on the linear relationship between the flow of water to or away from the freezing front and overburden pressure. The pressure at which no flow occurs is termed the shut-off pressure. At pressures less than the shut-off pressure water is sucked to the freezing front, resulting in ice lensing which can cause excessive heaving. At pressures greater than the shut-off pressure water is expelled from the freezing front, resulting in relatively small amounts of heave due to a freezing of a fraction of the original insight to water."

Stopping there, Dr. Slusarchuk, that's what we've been talking about, isn't it?

A Yes sir.

Q Yes, and the last sentence, "This water flow pressure relationship and the shut-off pressure depends on soil type,stress history and freezing temperature". Do you accept that as a general proposition?

A With regard to the stress history, we don't have the situation that is directly related there, where they are talking about remoulded samples all the time. We are actually sampling soils from along the test site, and the data that we get, the frost heave data, the rate of heave data, inherent in that data that we are getting and using is the stress history of the soil.

Q Well, Dr. Slusarchuk, I may be wrong, but I understood you to say about three minutes ago, that you had given no consideration to the stress history of the soil in doing these tests? Now, is that correct or is it not?

A Well perhaps I wasn't full enough in explaining what I meant at that time, sir.

WITNESS MORGENSTERN:

A Could I have a word here? The shut-off pressure as a phenomenom does depend upon stress history, but by evaluating the shut-off pressure of the soils that we encounter on this pipeline route by undertaking tests similar to those described in the paper that you cited, but on samples extracted from the route itself, the stress history is embraced within the test, and therefore we are testing samples that already reflect the history of

loading and unloading that they have been exposed to. In this sense, we no longer have to pay attention to the effects of stress history in the further testing that we do on the soils from the right-of-way.

Q Well, Dr. Morgenstern, are you telling us that it's quite consistent with your paper therefore, in the analyses that were done for this pipeline, to ignore the stress history, notwithstanding the abstract?

A The stress history -- it is quite consistent to ignore the stress history any further, because we are testing undisturbed samples taken from the route that contain within them, the stress history.

Q Okay. Isn't it clear that in an unprecedented project of this type, that you should have an understanding of the stress history?

A Consolidation testing on some of these samples to evaluate their stress history does go on, but the actual evaluation --

Q Where, where?

A Where?

MR. GENEST: Let him finish his answer before you ask him where.

MR. SCOTT:

Q Where does it go on?

A It goes on as part of the characterizing of the unfrozen soil. The evaluation of the shut-off pressure itself does not require further testing relatedto stress history, because it

contains the stress history.

Q Well -- I'm sorry.

A We are testing in our shut-off pressure test, a sample with a stress history that nature has put into it, and these constitute the bases for our further design.

Q Well first of all, who is doing the study of the stress history in these soils at the Calgary site?

WITNESS SLUSARCHUK:

A We have ran some consolidation tests on it, such as Dr. Morgenstern is referring to.

Q Well, are they reported on?

A I think they are probably reported on in here, sir.

We have some parts of the data report, such as the co-efficient of consolidation which is one aspect of that, but we don't have the actual stress history --

Q Well who has it?

A -- put in here.

Q I must say I misunderstood. I understood you to say first that no consideration has been given to this, Dr. Morgenstern has given an explanation that you know, I accept for these purposes, and now I understand you to say that some consideration indeed has been givento stress history.

A Well, I didn't say we didn't consider them. I said that at the stage we are

at, they're not significant to us, and that's what I thought you were asking. We don't work stress history into our predictive tool.

Now, as a matter of course with a lot of soil studies that you do, you run consolidation tests and so on, and we didn't incorporate it in this report, but data like that would be available to --

Q Are the samples that you are getting from along the route disturbed or not?

A They are what we call undisturbed samples, sir.

Q You're satisfied of that in every case?

A Well, there's always some disturbance whenever you take a sample.. This is an accepted aspect of sampling anything, and we have sampled in a manner that we feel our samples are undisturbed from our point of view.

Q Well, if the sample is disturbed, it's then that you particularly want to have a stress history? Isn't that so?

WITNESS MORGENSTERN:

A The procedure for sampling the undisturbed samples are commonly accepted techniques for sampling unfrozen soils. The degree of disturbance introduced by these sampling procedures is one that is part of the conventional knowledge of our geotechnical work.

Detailed evaluation of stress

history, it would seem to me would be of interest, but not essential to the bringing together the body of data for frost heave prediction and design.

Q Well does this mean then, that if you can get an undistrubed sample, you don't have to be conserned, or you don't have to consider, as I think Dr. Slusarchuk put it, the stress history of that particular sample?

A Yes.

If you had a sample that was very disturbed, and you could see it, you wouldn't use that, you wouldn't test it.

Q Well, are you satisfied to the point of assusrance that the samples that you have obtained from the valley and taken to wherever you take them to test, can be regarded as undisturbed samples?

A To the usual degree of satisfaction in our work, yes.

Q Dr. Slusarchuk, what significance, if any, do you attach to the development of these long cracks that have been seen on the surface, that appear to be from frost heaving at the Calgary site?

WITNESS SLUSARCHUK:

A That is just a shear plane, sir, due to the frozen soil moving up.

Q And what length are they?

A They are pretty much the length of the pipe.

Q Yes, and no doubt they will run along the pipe in the 200 mile sector that is alternately frozen and unfrozen?

A Yes, sir.

Q Yes. Are these good or bad or indifferent? What evaluation do you make of them?

A With regard to our frost heave analysis, I think they are indifferent.

Q Well, aren't they going to be a repository for run-offs?

A Well that's a different thing than frost heaving, sir.

Q Yes. But is there anybody on the panel who can speak to the question of what the consequences will be if they indeed are a repository for run-off along the 200 mile length of this pipe?

WITNESS CLARK:

A The water within the zone of influence of the pipe would freeze, and therefore the cracks would not conduct water beyond that frozen section.

Q Well now --

THE COMMISSONER: Excuse me. Did you say that the water would freeze?

A If the crack extended into the zone affected by the pipe, this frozen soil, the water would freeze in that frozen soil. I'm not sure in hindsight, if I've understood Mr. Scott's question.

Q Well that would block the flow downward at any rate.

A Yes.

Q Is that your point?

A Yes.

MR. SCOTT:

Q Is there any doubt about the question, Dr. Clark?

A Yes, that was the -- if I interpreted it correctly. You might have been referring to flow along the pipeline.

Q Well these cracks run along the pipeline?

A Yes, they do.

Q Along the edge of the pipeline?

A Yes.

Q Virtually its length, at least where there is any heave.

A Yes.

Q Did you understand that when you made your answer?

A Yes.

THE COMMISSIONER: Well, excuse me, the cracks would be parallel to the pipeline?

A They would, indeed, yes.

MR. SCOTT:

Q Well now, Dr. Slusarchuk, have you given any consideration to heaving from ice lensing of the soils above the pipeline?

WITNESS SLUSARCHUK:

A Yes, sir, some.

Q Well now, I ask you to envisage a situation in which the pipeline as a result of the remedies you have discussed, does not move. What is the extent of heaving that can be anticipated above the line, that is, above the pipe in the soils that are found there?

A It would tend to heave a certain amount, and as the pipeline started to operate and the frozen zone would develop over it, in the summer it would thaw back down and then it would more or less establish an equilibrium there, sir. It wouldn't be kind of an ongoing process, the way you have it beneath the pipe, because it would be more similar to the frost heaving situation that we are used to in the more southern latitudes.

Q Well, over what period of time is this heaving above the pipe likely to occur?

A Well during the first few months of operation.

Q Well, why is it that it won't occur indefinitely? There is no overburden to speak of?

A No,because the sun comes out in the summer and thaws down to it.

Q So I take it what is going to happen is the thaw is going to terminate the lensing annually?

A Yes, sir.

Q Yes. Well now, what ranges of heave do you contemplate under worst conditions

above the pipeline?

A Between the top of the pipe and the top of the ground, we contemplate very little heave, or a nominal amount of heave. A few inches or something like that.

Q Well let's take -- have you done studies on this?

A Well,we've done studies to the extent that we've done geothermal analysis on different situations --

Q Well that tells us the temperature, doesn't it?

A It tells you what's frozen and what isn't frozen.

Q All right, but what I'm asking is, have you done studies to measure -- have you done studies, assuming the pipe is perfectly stationary, on the extent of heave that occurs in the ground above it?

A We haven't done specific studies on that, sir.

Q Now I presume you had the opportunity to measure this at Calgary.

A Yes.

Q Did you measure it?

A Yes sir.

Q Is that reported anywhere?

A Yes, it should be reported in this here document.

Q Is there any chance that you can put me onto the page or the graph?

A Yes, just give me a second. It's reported as a separate study, sir, and the data is in here but you would have to -- we don't have it in here as a separate graph, and I'm not sure whether the data is actually presented in here from all the heave data. We could actually go and make a quick calculation right here to show you that. We do have that data.

Q well, I take it that you're not primarily concerned with it because it doesn't have to do with the movement of the pipe.

A We are also monitoring the ground surface. That is reported in here on figures 237, so we know what the pipe's moving and we know what the ground surface is moving across the pipe.

Q Well, I'm concerned with heave above the pipe that is related only to the lensing in the ground above the pipe, and perhaps you can, at a convenient opportunity, get those figures for

Mr. Genest and let us have them, based on your observations at Calgary.

A Yes sir, I could do that.

Q Yes, not in the next ten minutes, but when you have a convenient moment.

Now I take it that --

MR. GENEST: Mr. Scott, I just want to make sure of what we're required to do so there will be no quarrels about it.

MR. SCOTT: Well, let us have a report of the measurements at the Calgary test-site which reflect heaving above the pipe, that is lensing and the consequent lift above the pipe.

MR. GENEST: Heaving that is lensing above the pipe.'

MR. SCOTT: Q Now, Dr. Slusarchuk, I take it that that lensing will occur not only on top of the pipe but on the sides of the pipe as well

A Yes sir.

Q Have you done any mèasurements or do you have the statistics which will -- or the readings which will tell us the lift associated with lensing in those areas?

A I think we have the information that we could provide that.

Q Thank you very much.

A And you want the heaving to the sides, but that is physically located in elevation

over top of the centre line of the pipe. Over top of the pipe, like over the pipe there's no question, we just talk about the pipe to the ground surface; but now at the side it starts to go all the way around and underneath the pipe, and all you're interested in is the heave of the ground that's to the side?

Q Above the natural ground level. Have I made myself clear?

A No sir.

Q Well maybe I don't understand. I'm sorry, the heave to the edges of the frost bulb on each side.

MR. GENEST: The heave on each side, I just don't follow that.

MR. SCOTT: Well, I think the transcript tomorrow, Mr. Genest, I'm sure it's not going to be --

MR. GENEST: Well, I understood clearly what you said, and I know the English words that you used, but what you mean escapes me entirely. Heaving to the side is a concept that escapes my limited brain. Perhaps my panel will know.

MR. SCOTT: I'm surprised to hear that.

(LAUGHTER)

MR. GENEST: You've known my brain a long time, Mr. Scott. So if my panel later tells me that that's incomprehensible to them, I'd just like some explanation of what it is we're getting at.

MR. SCOTT: Dr. Slusarchuk, do you have some comprehension of what I was talking about?

WITNESS SLUSARCHUK: Well, I am not clear on what you're after when you start talking about over the side of the pipe. There's only a certain amount of soil between the top of the pipe and the ground surface right above the pipe, and that I'm quite clear on what you're after; but when you start to go over the sides, do you want me to give you the heave of that soil that is in elevation above the top of the pipe, is that what you're after?

MR. GENEST: ARE you having the same trouble, Mr. Scott?

MR. SCOTT: I'm getting a diagram.

A Perhaps I --

Q Well, is it possible to prepare for us perhaps in a diagramatic way the -- a line showing the heave from the outside line of the frost bulb on one side across the mound and over to the outside limit of the frost bulb on the other?

A You already have that, sir, on figure 237. For example, for the control section, maybe I can just carry that on. The ground directly over the pipe -- and this would be the ground between the pipe and six inches over the pipe, I believe that's where that -- or six inches between the normal ground surface there, if it heaved in 200

days, are you on figure 237, sir?

Q Yes.

A It has heaved somewheres about say .8 feet. The pipe at the same time, if you go to figure 256, has also heaved approximately .8 feet at 200 days, so you can see that they are virtually heaving at the same rate.

Q It's difficult to follow that with not all of us looking at the diagrams. Would it be too much to ask that you prepare a summary of your measurements at Calgary as best you can?

A Well --

MR. GENEST: Showing what, Mr. Commissioner? I want to be helpful to Mr. Scott.

MR. SCOTT: Showing the extent to which above the stationary pipe or above the top of the pipe heaving has occurred as a result of -- heaving has occurred.

A Well, sir, is not my answer now which I thought I couldn't dig out of our figures not sufficient for you? Perhaps if you'd care to look at the figures I could give you the answer that shows you that the pipe is heaving at the same rate as the ground above it, and therefore the heaving that is taking place over top of the pipe is virtually nil. Looking at the control section, it would be figure 237.

Q Well, the difficulty is that if we all followed it in our charts, it may be

possible for us to interpret the charts. I wonder if as a matter of convenience it isn't possible to tell us what those measurements are, as you've been able to do in other cases? The diagram is made more difficult to understand by virtue of the tilt to the pipe.

A Well, in both cases we've been plotting the heave at the centre line of the pipe and that's what's given on figure 256, and the heave that is given of the ground surface is also at the centre of the pipe.

Q All right, what is the dimension of heave that is attributable merely to the earth above the pipe at Calgary?

A It's very small, sir.

Q Well, can you tell us what it is? The maximum you observed.

A For the control section, sir?

Q For any section, or for all of them, that's really what we want.

A O.K., well then I can't -- I can only give you the control section right now. I'll give you the others later.

Q I'd be obliged, thank you very much. I take it that that answer, Dr. Slusarchuk, will be for one year?

A Well, it will take me a couple more days, I don't have the data with me beyond day 200, but I can give it to you for one year if thats

what you're after.

Q Thank you.

MR. GENEST: You won't settle for 200 days?

MR. SCOTT: Well, I'll settle for what you have, what you have conveniently. The problem, Mr. Commissioner, as Mr. Genest knows, is that studies have been prepared to reflect the movement of the pipe. It's our proposition that there may be some movement that is unconnected with the pipe except by virtue of the fact that the pipe has created a frost bulb. In terms of environmental concerns we may be interested to know the extent to which that exists.

A You're not correct to say, sir, that tests were designed to monitor the heave of the pipe, because in each cross-section we have approximately 25 heave gauges that are monitoring the heave of the soil at different depths and different distances away from the pipe, and we only have three heave gauges monitoring the movement of the pipe on each section.

Q I don't want to argue but what I'm saying is however the test was designed, the study that is produced shows us the heave of the pipe, it doesn't deal with the heave above the pipe, assuming a stationary pipe. Now I understand that you'll be able to get that for us and I'm grateful, on a 200-day basis.

THE COMMISSIONER: I think I

understand what this argument has been about. You have been measuring the heave, the extent to which the pipe itself will heave and what Mr. Scott is after is the extent of the heave on the surface of the earth.

A Yes sir, and we've got that, and we've got those figures in here.

Q At 200 days?

A Yes, at 100, 150 and 200 days.

THE COMMISSIONER: Well, at least you know what you're arguing about, and I think that's important.

MR. SCOTT: It's encouraging.

Q Dr. Clark, let me ask you a couple of questions about the remedial measures that you propose for the movement of drainage water, and the first relates to your solution which is a berm break for surface drainage/ water. Now, I take it that a berm break is really a cut in the overburden. May I begin again? A berm break is not necessary, except in a case where there is an overburden.

WITNESS CLARK: A berm break would be used where there is a spoil mound or a berm to inhibit frost heave in frost susceptible soil.

Q And the break, I take it, is simply a physical cut of some width in the berm or overburden.

A The ground would not be built up over the original level of the drainage course

there.

Q So that what happens is that you stop your overburden for a period of time and that becomes the berm break.

A That's correct.

Q And the berm break is in fact the -- the base of the berm break is in fact the original ground level.

A That's correct.

Q Now, what happens when the -- when frost heave occurs, and the ground all along the pipeline is raised at the centre?

WITNESS CLARK:

A That would depend upon the nature and frequency of our berm break, but that ground would come up there.

Now, if the berm break was in a soil where the -- it could erode, it would downcut by itself, but our proposal there would be by maintenance to keep that bottom of the berm break at that level, --

Q Well --

A -- so it could drain water.

Q -- let's see if I understand the question.

MR. GENEST: Mr. Scott, please let the witness finish his answer.

MR. SCOTT: I'm sorry.

MR. COMMISSIONER: I think we might break for a cup of coffee and then take another run at this in a few minutes. Would that be all right, and I think we're in need of some kind of break.

(PROCEEDINGS ADJOURNED)

(PROCEEDINGS RESUMED PURSUANT TO ADJOURNMENT)

CROSS-EXAMINATION BY MR. SCOTT, CONTINUED:

Q Dr. Clark, to revert to the problem I was trying to deal with before, let me give you these assumptions. You have, as I think you have told us, the berm break at ground level. You have frost heave, elevating the pipe, the ground above the pipe, let us say a foot; how are you going to clear that berm break so the water won't have to go over a hump that is one foot high?

A That particular section which would be frozen in the winter, would thaw in the summer, so it would be less than the ground that remained frozen under the berm, for instance.

It would then settle a certain amount, it might still be above the level that it started out at. There would probably be some erosion there, and occasionally on the maintenance schedule it would be required to lower that physically.

Q Well Dr. Clark, the berm break raised a foot that we are talking about --

A Yes.

Q -- is not going to melt during the spring run-off, is it?

A It would start to melt as soon as water got to it.

Q Yes, but there would be lots of water going over there, or wanting to go over there before the ground is thawed a depth of a foot?

A I would think that with

running water that the thawing to a foot would occur very rapidly.

Q Well, I suggest to you that this is a problem that can only be solved by virtually annual maintenance of the berm breaks?

A We would see for about the first three to five years, maintenance there.

Q And that would mean going in and cutting them out? Doesn't it?

A It would mean going in with a -- I would visualize a couple of people with a shovel to open up the area again.

Q Yes.

A A hand shovel, not a mechanical one.

Q Well now, the next matter is drainage through the Templeton Wall.

A Yes, sir.

Q As I understand there, you are going to put a tube of some description from one end of the -- or from beyond one extremity of the frost bulb through the frost bulb out the other end?

A When Mr. Templeton was discussing that, I mentioned that we had not yet idetified any area where that would be required. We saw that as a solution if there was a shallow aquifer that carried water through the winter.

Q Am I correct that you said to Mr. Templeton that if there was -- let me put it this way. Mr. Templeton's proposition to you, I think

was that the water as it passed through the frozen bulb, would freeze and block the bulb? That was what --

A That is what he suggested, yes.

Q Yes, and I understand your answer to that to be that if the water is flowing quickly, it won't freeze?

A I couldn't give you precise numbers, but for the six inch diameter pipe, for example, with only one inch of insulation around it, the calculations would indicate that the flow required would be about one thousandths of a cubic foot per second, to keep it from freezing, a very small flow.

Q Well, wasn't your answer to Mr. Templeton, that in the event that there was a very small flow, you would not feel it necessary to run the lines through the bulb?

A If the flow was insignificant.

Q If the flow was relatively large, however, you would, and in your judgment it would not freeze within the bulb and block the pipe?

A That's correct, yes.

Q Well let me put this situation to you. It seems to me there is an intermediate case, a case of a flow that is great at one season of the year, but which begins to trickle and may ultimately dry up. Now what is going to be done there?

A Well, if it's great at one

season, I would assume that you mean the summer season --

Q Yes.

A -- under that circumstance, we wouldn't propose to carry the water through the pipe. We would carry it through the berm breaks, in other words, let it surface, and it would then be carried through the berm breaks.

Q Well isn't there inherent in this, the risk that if there is any volume of water, you will collect great pools of water on the upside of the pipe?

A It would depend on the slope entirely, the size of the pool. There could be minor pools, but not what I would describe as a great pool.

Q In any event, that is the solution that is proposed for cases where there is a flow that -- a substantial flow that diminishes in another season?

A That's correct.

Q Is there any prospect that when that happens, an icing will be created that will last through the season ?

A Well the substantial flow is occurring in the summer, as I understand the scene that you set, so there would be no icing there. For an icing to occur, there would have to be substantial flow in the winter, in which case we would be carrying it through the frozen bulb.

Q What about the autumn?

A You would like to extend the substantial flow into the autumn?

Q Yes.

A If there is substantial flow, it would still come to the surface in the autumn, I would think.

Q Well, will an icing not form?

A I'm not sure that it would. The combination of circumstances required to form an icing.

Q Would you agree with me that this solution needs a lot of attention?

A I think that the particular areas need a lot of attention, but we are talking about an area where we placed the berm to inhibit frost heave. We are also talking about sloping ground because for there to be flow the ground has to slope, and I would suggest that the amount of sloping ground in unfrozen soil where we might be required to use this particular configuration, is less than half of 1% of the length of the line in the discontinuous zone.

Q Well, is that --

A So substantial attention has to be given to those specific locations, but it's in total, not a very great length of line. So it's not substantial in quantity.

Q Have any studies or any

work been done about, or any testing done of these remedies, or is it again a conceptual response to a problem.

A Well, we haven't tested this in the field, no.

Q Have you tested it anywhere?

A We have analyzed the scope of the problem, I think, to bring it into perspective. We have developed what we feel at this time are solutions to the problem. We have subjected those to analysis and have -- feel that they will work.

Q Well, does that mean frankly that you've analyzed it and you've sat around and talked about it and you think this is the way it's going to be done?

A If I understand you, you're asking if we have carried water through a frozen bulb in discontinuous permafrost areas, and there has just been no opportunity to do that.

Q Well, this wasn't tested at Calgary.

A It couldn't be tested at that test site.

Q Why not?

A Well, there just isn't sloping ground there, the permeability of the soil is very low.

Q And you didn't consider it desirable to simulate one?

A It wasn't part of our objective.

Q Well, the Assessment Group raised it, the question of frost heaving above the chilled pipe, and Mr. Genest in the canned evidence at page -- at the addendum, page 3, sets out the concern and the response --

MR. GENEST: It's not my evidence, Mr. Scott. It's the panel's.

MR. SCOTT: There's some disadvantage in afternoon sessions.

Q I don't want to go through it again, Dr. Clark, but I take it that the defence is that the -- any heaving that will result is going to be minimal, for the reasons that are fully set out on pages 3 and 4.

A We're dealing here with frost heaving, as I read the page concerned, and I'll read it again to make sure we're looking at the same thing.

> "Frost heaving around pipe buried in permafrost PAAG states, page 170, that although the rate of water migration in frozen soil is low, it could produce significant heave over the long operating life of the pipe."

So that we're talking about not the discontinuous permafrost zone now, but the frost heave that could occur in continuous permafrost, is that correct?

Q Yes, and the nature of

the problem, as I understand it, is a situation in which you have the chilled pipe at a lower temperature than the frozen soil above it.

A Yes.

Q Well now, you have listed -- and I won't ask you to go through it again because you've done it in detail -- your judgment and the reasons for it in support of the proposition that the heaving that results will be very modest.

A Yes, that's correct.

Q Well now, and I understand that, is theresomeone on the panel who can compare the process to which that concern relates with the process of frost heaving in unfrozen soil that we have been discussing this morning? Leave aside the dimensions of the problem. Is the process the same?

WITNESS SLUSARCHUK: The frost heaving in frozen soil or in the permafrost, the driving gradients are the thing that moves the water from point A to point B to cause an ice lens, for example, is a thermo-gradient, and the --

THE COMMISSIONER: The water moves toward the --

A From the warmer part of the permafrost still frozen, to a colder part of the permafrost.

Q Yes.

A And one of the reasons that this does move is according to a law that is given

/of Gibbs free energy. the name of

(LAUGHTER)

MR. SCOTT: I'm familiar with that law, Dr. Slusarchuk.

MR. GENEST: We know it isn't free.

MR. SCOTT:

Q You are playing to the gallery, Dr. Slusarchuk, now answer the question.

A No sir, that is the terminology that it's known by, and the -- at different temperatures,the ice in the water, the water that is unfrozen in the permafrost, is at a different state of energy than a point some place distant that's at a different temperature, and it's this temperature difference that wants to drive the water from one place to the next place, and so that's the mechanism by which the water is tending to move in the frozen -- in the frozen soil.

Q Could I interrupt you? Do I understand that to be a different mechanism than the mechanism that operatesto create heaving in unfrozen soil?

A It's a different mechanism operating in the moving water in the frozen soil, than is operating in the unfrozen soil bringing the water from the unfrozen soil to the frost front.

Q In the frost heave situation that we've been discussing this morning?

A Yes, sir.

Q Are there other differences in the two models, the frozen ground model and the unfrozen ground model?

A Well the -- I'm not that

-- I'm really not that terribly familiar with any of the other differences that might exist; . that to me seems to be the major difference, other than that pressure seems to affect the mound of water that is moving in the unfrozen soil, whereas the people that are doing physical research in the frozen soil haven't come up or been talking about that sort of thing that I'm familiar with.

Q Your dilemma seems to be the same as those -- as that affecting those who advise me. Are you aware, and this is the purpose of the question, are you aware of any report or study or monograph or paper that deals with this phenomena?

A Which one are you talking about now, sir?

Q The question of the development of the process in frozen soil?

A Yes, sir, there are alot of papers on that.

Q Where do we find them?

A I can give you several tens of them, if that's what you're after.

Q Well I would be grateful for that, but have you done -- has Northern Engineering done any work on this phenomena that's available?

A Yes, we've had a close look at that, yes sir.

Q Is there any report or study within the possession of Northern Engineering that touches it?

A We have done the study , sir, we have not -- we do not have a report in even draught shape yet, but we have been doing a study on that over the past few months.

MR. SCOTT: Well, Mr. Commissioner, perhaps I can leave that subject in that way, and invite Mr. Genest to consult with me to determine how best the information that may be in that putative paper can be made available to us and we don't have to trouble you and take your time on that subject.

Mr. Commissioner, those were the questions that I anticipated I would have asked and finished by one o'clock.

MR. COMMISSIONER: Well, if you're suggesting we adjourn now until tomorrow morning, I think I'll go along with that before anybody has a chance to protest, so we will adjourn till 9 in the morning then .

(PROCEEDINGS ADJOURNED TO 9:00 A.M., THURSDAY, APRIL 10TH, 1975)